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ANNUAL REPORT

OF THE

BOARD OF DIRECTORS

OF THE

Chicago Astronomical Society,

TOGETHER WITH THE

REPORT OF THE DIRECTOR

OF THE

DEARBORN OBSERVATORY,

1880.

CHICAGO:
KNIGHT & LEONARD, PRINTERS.
1880.

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" " 1882 — John Forsyth, Robert Warren; H. C. Ranney.
" " 1883 — Clinton Briggs, W. T. Baker, C. H. S. Mixer.

DIRECTOR OF OBSERVATORY.

Prof. G. W. Hough.

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1880

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REPORT.

Annual Report of the Board of Directors to the
Chicago Astronomical Society:

The policy of your directors during the year now ending, as through several preceding years, has been to preserve the society's property and to promote the use, in the interest of science, of your valuable instruments by those who were competent and who could so use them without pecuniary compensation.

The Observatory has been, during the year, in the care of Prof. G. W. Hough, to whom, with Messrs. Elias Colbert and S. W. Burnham, astronomical science is indebted for such use as has been made of it.

That Dearborn Observatory should not occupy this position your Directors are well aware, but this conserving policy has seemed the only one open.

Those who were most active in creating and for many years supporting your Observatory, were rendered powerless by events familiar to all, and it has not been thought best to make special effort to create a new fund until our citizens have realized the benefits of more prosperous times.

Whether the coming year promises good results from such an appeal, is a question which may well engage the most thoughtful consideration of your new Board of Directors.

The Treasurer's report shows a balance on hand of $444.09. The incidental expenses of another year will consume nearly or quite this amount, and this suggests very forcibly the propriety of looking carefully to the future.

The report of Prof. Hough, covering the work done in the Observatory by himself and Messrs. Colbert and Burnham during the year, is herewith submitted, and made a part of this report.

Respectfully submitted in behalf of the Directors.

C. H. S. Mixer,

Chicago, May 13, 1880. *Secretary.*

REPORT OF THE DIRECTOR

OF THE

DEARBORN OBSERVATORY.

To the Board of Directors of the
Chicago Astronomical Society:

GENTLEMEN: The following brief report will exhibit the nature and amount of the astronomical work carried on at the Dearborn Observatory during the past year. It includes, moreover, such details of the construction and operation of the instruments in use, as well as of original investigations and methods, as it is thought would be of interest to the Society and friends of the institution.

For the first two months after I was placed in charge of the Observatory my time was in great part occupied in becoming familiar with the instruments and in making such adjustments and changes as were deemed necessary.

The clocks and chronometer, used for mean and sidereal time and for transmitting time signals, were removed from the third to the second floor of the University building, in a room fitted up for their reception. This room has also been used for the library. During the winter the temperature has been kept as nearly uniform as possible, in order to secure better rates on the clocks.

I have made a careful investigation of the going of the two clocks and the chronometer, to ascertain the changes due to temperature. The discussion of the observations extending over some months showed an unusually large error in the compensation for both clocks, but by reading the thermometer twice each day, and applying the correction depending on the temperature, it has been possible to keep the time for one week inside of one second. Except, however, on two or three occasions of long-continued cloudiness, meridian observations have been secured on at least two days in each week, and the correct time has been known daily within one-quarter second.

The compensation of the sidereal clock furnished by the Western Electric Company has been partially corrected by adding mercury, but the jar has not sufficient capacity for a perfect adjustment.

The going of the Howard mean-time clock has been materially improved by doubling the driving weight, thereby reducing the error due to change in the oscillation.

As heretofore, time signals have been sent daily from the Observatory to the Western Union Telegraph Company's office, for distribution to the railroads and jewelers.

Shortly after my advent in the Observatory I set about the construction of a chronograph, for use with the meridian circle, the great equatorial, and for the comparison of clocks for the time service. About the 1st of August last the instrument was completed and mounted in the clock-room at the Observatory, where it has been used daily since that period, and is found to give very satisfactory records. I may add that the machine is of my invention, and was constructed at my own expense. The method for securing uniform circular motion is similar in principle to that employed for a printing chronograph, constructed by me some years since at the Dudley Observatory.

MERIDIAN CIRCLE.

The meridian circle was made by Repsold & Son; it is provided with one circle divided to $2'$ and read by four microscopes to $0''.1$. The aperture of the objective is six inches.

It has been used on every clear day or night for time observations, and for fixing the position of a few stars used with the equatorial and not found in any catalogue.

The number of meridian observations amount to seven hundred — in right ascension. Although primarily made for time only, they nevertheless furnish differential corrections to the places of the stars of the standard catalogue of the "Astronomische Gesellschaft," some of which appear to be considerably in error.

The level error has been determined whenever observations were made, usually by directing the telescope to the nadir, and observing the reflected image of the middle wire. The spirit-level, however, has been occasionally employed, but the former method is to be preferred as giving more reliable results.

The collimation has been determined by reversal in the nadir. It has been very steady, and not amounting to more than one second of arc during the year. Contrary to the usual condition of things, nadir observations can be made here, without any special appliances, at almost any hour of the day or night. The passing of railroad trains or vehicles has very little effect on the quality of the images.

In July last the level and azimuth errors were reduced to zero, but it was soon found that the instrument was subject to considerable change of position, due to temperature. During the coldest weather of winter the azimuth reached a maximum of $+20''$ of arc, and the level of $+5''$ of arc; at the present time the azimuth is nearly zero, while the level is $-6''$ of arc. As these changes are gradual, although rather larger than are ordinarily found in instruments of this size, they will not impair the accuracy of the observations.

The four reading microscopes have been adjusted at equidistant points on the circle, and the runs of the screws made sensibly equal to zero.

A few observations for zenith-distance indicate a correction to the assumed latitude. As the determination of this element, from the observation of circumpolar stars at the upper and lower culminations, both direct and by reflection, would require considerable time for its proper execution; since at the same time the division errors of the circle and the flexure of the telescope should be investigated, I have not yet been able to undertake this necessary duty.

The machinery for moving the dome has been a constant source of perplexity, and numerous plans have been considered for its improvement. During cold weather it was almost impossible to move it at all, and hence observations were confined to a very limited portion of the heavens. It was provided with a double set of driving gear, the power being applied simultaneously at two opposite points of the circumference. The pinion gearing in the contrate cog-wheel was driven by endless chains. As these were of unequal length any great change of temperature would cause them to act unequally, the one tending to retard the efforts of the other. A short time since I removed one set of the chains and shafting connected with them, driving the dome from one side only. The improvement in the working of the machinery exceeded my most sanguine expectations. I estimate the power now required to move the dome at not more than one-third of what was formerly necessary, and I presume in cold weather the difference will be still more perceptible.

Owing, however, to the great size and weight of the dome, even in its present condition, it requires considerable time and muscular effort to turn it half round.

At a meeting of the Society it was suggested that some motive power be employed for this purpose—either a hydraulic or gas engine. Under existing circumstances a motor of one-half nominal horse power would be amply sufficient. I would again renew the suggestion, since a contrivance of this sort would greatly facilitate observations, and it would enable the observer to work on any portion of the heavens on the same night.

THE EQUATORIAL.

The equatorial has an object glass of 18½ inches aperture and a focal length of 23 feet. It is provided with a parallel wire micrometer and driving clock. The eye-pieces used with the micrometer magnify from 120 to 925 diameters. The value of the micrometer screw was determined by transits of equatorial stars recorded on the chronograph, and was found to be essentially the same as has heretofore been used by Mr. Burnham for his double star measures.

Observations have been made on almost every favorable night, usually on such objects and phenomena as cannot be reached with smaller instruments.

My own experience during the past year, taken in connection with what has hitherto been accomplished by Mr. S. W. Burnham, on difficult double stars, leads me to believe that it is superior to any telescope in Europe, and is only surpassed in size and light power by the great refractor of the United States Naval Observatory.

Mr. Burnham speaks on this point as follows: "I know of no object, faint or otherwise, which has been seen at Washington or elsewhere, that cannot be seen perfectly here and accurately measured."

The object glass seems to be equally good up to its full capacity, since reducing the aperture has no appreciable effect on the definition.

An instrument like this should principally be devoted to difficult objects, and for the study of physical phenomena requiring high magnifying power combined with good definition.

The faint periodic comet (Tempel II, 1867) was observed on six nights by myself, and on two nights by Mr. Burnham, between June 7 and June 18.

The comet discovered by Swift was observed on eleven nights by myself, and on two nights by Mr. Burnham, between June 23 and August 16.

On the 27th of August last, in connection with Prof. Colbert, I began a series of observations on the planet Jupiter. These were continued on every favorable night during the whole opposition, the last one being secured on February 11, 1880. Owing, however, to unusually bad weather, but few observations could be made after the middle of October. As some of these have an important bearing on the physical constitution of that planet, it may be of interest to the society to give a brief abstract of the observations made, and the conclusions drawn from a discussion of them.

THE FIGURE OF JUPITER.

It was early recognized by astronomers that the disc of Jupiter was elliptical. The amount of ellipticity, as determined by different observers, varies from 1-13.5 to 1-20, showing a very large margin of uncertainty.

With a magnifying power of 638, the disc of the planet was measured on eight nights by myself, and on six nights by Prof. Colbert. My own observations include eight measures of the polar, eight of the equatorial, and five of the conjugate diameters. Prof. Colbert's includes six of the polar and five of the equatorial.

With a magnifying power of 389, the polar and equatorial diameters were measured on five nights by Prof. Colbert and myself.

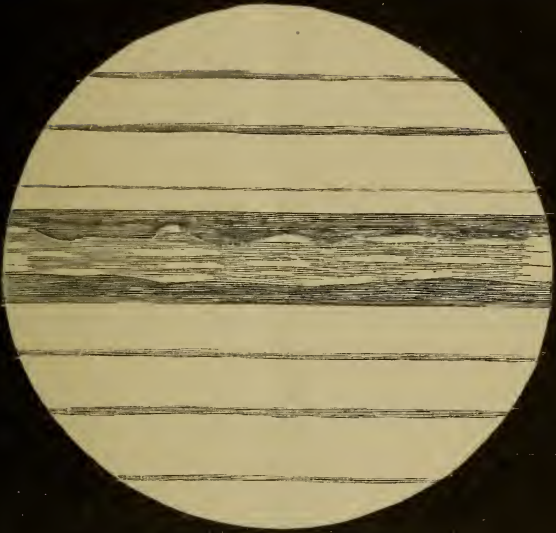
The reduction and discussion of these observations give the ellipticity as follows:

Magnifying power, 638.		
	Hough	1-16.23
	Colbert	1-16.73
Power, 389		1-16.76

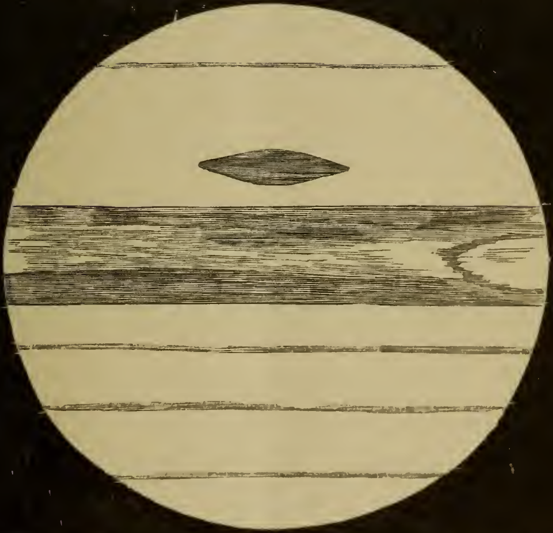
The transit diameter was also observed with the chronograph on six nights. Using the ellipticity as given by my own observations with power 638, and computing the values of the conjugate and transit diameters, making angles of 45° and 24° respectively with the major axis of the spheroid, the difference between observation and computation is found to be 0″.04 and 0″.01, quantities entirely insignificant, showing the figure of Jupiter's disc to be a true geometrical spheroid.

It may be stated that the English Nautical Almanac uses Struve's value of the diameters, 38″.33 and 35″.54, ellipticity 1-13.71, while the American Nautical Almanac uses 38″.53 and 36″.18, ellipticity 1-16.40.

JUPITER



6H.-30M. Oct. 21st. 1879



9H.-22M. Oct. 29th. 1879

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The absolute value of the diameters was observed as follows:

	Polar.	Equatorial.	Conjugate.	Transit.
Hough, power 638,	36″.319	38″.704	37″.529	38″.295
Colbert, " "	36″.030	38″.316		
H. and C., " 389,	37″.388	39″.764		

A comparison of the absolute value of the diameters, as measured with powers 638 and 389, led to an interesting result, and one which has an important bearing on the micrometrical measurements of luminous discs.

On looking at the moon, or any luminous object, either with the naked eye or telescope, it appears larger than it really is. This enlargement is technically called irradiation. The law fixing the amount of irradiation is unknown. Our knowledge on this subject is almost entirely speculative. It is supposed to depend on the size of the object-glass, the condition of the image, the eye of the observer, and possibly the magnifying power. Small telescopes are presumed to give a larger value for this quantity than large ones.

The excess of diameter, as given by power 389, amounts to 1″.18 on the polar and 1″.21 on the equatorial diameters at the mean distance of the planet from the earth, or a mean difference of 1″.56 as observed. The values being so nearly identical for both diameters, measured by two observers, shows it to be a real quantity, and not the result of erroneous measurement.

An investigation, having for its object the determination of the law defining the amount of irradiation for micrometer measurements of luminous discs, is one on which the great refractor could be very profitably employed.

EQUATORIAL BELT OF JUPITER.

The angle of position of the north edge of the equatorial belt, was determined by micrometer measurement on eighteen nights between August 27, 1879, and January 14, 1880. These observations show that the belt had the same direction around the whole circumference, that it maintained this direction without any change during the whole opposition, and that it was precisely parallel to the equator of the planet.

The observed mean position of the belt was —23°.7.

The computed mean position of Jupiter's equator, —23°.7.

The distance of the north edge of the belt from the planet's equator was determined on ten nights, between September 3, 1879, and January 14, 1880. The observations indicate that it was fixed in latitude; it did not shift north or south an appreciable amount during the opposition. The width of the belt was also measured on nine nights; and although the measures differ among themselves to the extent of one second of arc, yet it is difficult to decide whether any radical change took place in its apparent size during the period covered by the observations.

The position on the disc of the six faint belts, three in the northern and three in the southern hemisphere, were determined with the micrometer a number of times between September 10 and October 24.

The following numbers indicate the belt system of Jupiter during the opposition of 1879. The observations have all been reduced to the mean distance of the planet from the earth, and show the distance of each belt from the equator.

Equatorial diameter, 38″.70.
Polar diameter, 36″.32.

No.	North.	
1	+ 15″.10.	
2	+ 9″.78.	
3	+ 5″.98.	
4	+ 2″.59.	North edge equatorial belt.
	− 3″.18.	South edge equatorial belt.
5	− 5″.83.	
	− 6″.94.	Red spot.
6	− 9″.83.	
7	− 13″.84.	

An examination of these numbers shows that the belts were arranged symmetrically on either side of the equator, the great red spot coinciding very nearly with belt (5).

It may be proper to remark that the faint belts are not seen with small instruments. All the pictures of Jupiter during the past opposition, which have come to my notice, simply show a darkening toward the poles, and not separate belts. That they were permanent features, cannot be questioned, as they were always seen under ordinary atmospheric conditions up to the end of October. The power usually employed was 638. When the definition was not good enough to use this power, the observations were not considered of any value for determining suspected physical changes.

The middle of the great equatorial belt was subject to gradual change in its appearance between September 1 and November 1. During the earlier portion of this period it was made up essentially of three separate belts, approximately equal in width. It gradually formed in two almost equal portions, with a rift extending through a large part of the circumference of the planet.

The accompanying wood-cut shows the great red spot, the belt system, and to some extent the structure of the great equatorial belt.

The color of the equatorial belt was reddish-brown—brick color; that of the great spot was similar, but more brilliant.

The equatorial belt was visible up to the edge of the disc with very slight diminution in color. The red spot was frequently seen at the edge, when only partially on the disc, and the color appeared sensibly the same as when near the center.

After December 1, the faint belts in the northern hemisphere continued visible, but on the southern hemisphere there was simply seen faint markings on the center of the disc.

RED SPOT.

One of the most remarkable features on the disc of the planet was the great red spot on the southern hemisphere. The study of this object was begun on September 11 and continued until February 10, 1880.

Its position from the equator was measured on eight nights, including one by Prof. Colbert.

The observations during September and October show it was fixed in latitude during that period. A single observation on February 10, after an interval of nearly three and one-half months, shows an apparent displacement of one-second of arc, possibly due to unavoidable error of measurement.

Its length and breadth were measured on nine nights, of which one measure of length and two of breadth were made by Prof. Colbert.

The mean value of its length, at the mean distance of Jupiter from the earth, was 12″.73, and the breadth 3″.56, as seen on the center of the disc. The length appeared to vary to the extent of 2″ of arc, and the breath about the same amount.

Owing to the irregular outline of the object it is difficult to decide whether any actual change took place during this interval, or that the discrepancies in the measures are simply due to bad seeing. Measures made during the present opposition will, of course, afford positive information on this point.

Observations on the position of the spot for ascertaining the rotation period of the planet were begun on September 25 and concluded on February 10, 1880. They consist of micrometer measurements of the distance of the center of the spot from the two limbs of the planet disc. At my request Prof. Colbert has made the computations necessary for determining the rotation period. He has obtained $9^h\ 55^m\ 34.2^s$ as the time of sidereal rotation.

On the morning of May 7, 1880, the spot was seen on the disc, and its time of transit over the central meridian approximately determined by micrometric measurements. Owing, however, to the low altitude of the planet, and the approach of daylight, no measures of its length, breadth, or position, could be secured.

The above period satisfies all the observations, including that of May 7, within the probable errors of observation.

The value hitherto considered the most probable was

$9^{h}\ 55^{m}\ 26^{s}$, differing about eight seconds from the present one, or equivalent to an error of one-quarter rotation in one year.

Observations made during the present opposition, combined with those of last year, will probably serve to determine the rotation period within 0.10^{s}.

The diameters of the four satellites of Jupiter were measured on three nights, with the following results, at the mean distance:

1st.	2d.	3d.	4th.
1″.114	0″.980	1″.778	1″.457

SATELLITES OF URANUS.

In the month of March we began the observation of the satellites of Uranus. The two inner satellites, according to the Washington observers, are the most difficult well known objects in the heavens.

When I undertook their observation it was doubtful whether they would be distinct enough in our telescope to make satisfactory micrometric measurements. I am happy, however, to state that near the time of opposition they can readily be seen and measured under ordinary atmospheric conditions.

The observations on the two inner satellites were not begun until a month after opposition. And, notwithstanding an unusual amount of cloudy weather, Umbriel, the faintest, was seen on three nights, and Ariel on four nights.

The two outer satellites are comparatively easy objects at any time within two months of opposition.

Micrometrical observations were secured as follows:

Ariel	3 nights.
Umbriel	1 night.
Titania	5 nights.
Oberon	5 nights.

In addition, Mr. S. W. Burnham observed:

Ariel	1 night.
Titania	3 nights.
Oberon	2 nights.

Donations to the Library, amounting to fifty volumes and pamphlets, have been received from American and foreign institutions and individuals.

Mr. S. W. Burnham, as heretofore, has had the use of the great equatorial for double star observations. During the past year he has continued his work on difficult objects, and the more interesting binary systems, and also remeasured such stars as seemed to require it, for his general catalogue. During the year his catalogue of new doubles, discovered with the great telescope, has been published by the Royal Astronomical Society. He has also discovered a number of probable new binary systems. He was absent for three months for fixing the site for the Lick Observatory, of California.

I am pleased to acknowledge his interest and assistance in comet and satellite observations, and to thank him for the loan of star catalogues and other publications not in the library.

G. W. HOUGH,
Director.

Chicago, *May* 13, 1880.

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E. Colbert.
W. S. Gurnee.
H. N. Hibbard.
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ELECTED DIRECTORS.

Till May, 1882—John Forsyth, Robert Warren, H. C. Ranney.
" " 1883—Clinton Briggs, W. T. Baker, C. H. S. Mixer.
" " 1884—P. H. Willard, Dr. H. A. Johnson, Murry Nelson.

DIRECTOR OF OBSERVATORY.

Prof. G. W. Hough.

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1880/81

REPORT.

Annual Report of the Board of Directors to the
Chicago Astronomical Society:

As through the preceding year, Dearborn Observatory has been in the care of Prof. G. W. Hough, to whom, with Messrs. Elias Colbert and S. W. Burnham, astronomical science is again indebted for such use as has been made of it.

At the time of the Great Fire, the Society had entered into a contract with the city for furnishing standard time to the City Hall, and had begun the performance of its duties under that contract. Your Directors considered that no good reason existed for allowing this contract longer to lie dormant, and upon moving in the matter were met in a very kindly spirit by the city government.

The result, is a renewal in a form which should be satisfactory to the Society, and will we think be of decided convenience and benefit to the city.

In order that this contract may be perfectly fulfilled on the part of the Society, your Directors have ordered from the Messrs. Howard & Co., of Boston, two new clocks, which will cost about $1,000. The cost of running wires and other equipments has been $574.

The friends of the Society have contributed the funds required to meet the immediate wants of the Observatory; but the Society is in pressing need of a permanent endowment, which will not only enable it to continue its present course of action, but to enlarge its sphere of astronomical work and take an honorable place among the prominent astronomical observatories of Europe and America. We believe the time is at hand, when our public-spirited citizens will cheerfully contribute the amount necessary for the accomplishment of this important object.

The Treasurer reports a balance in hand, available for current expenses, of $170.01, and the sum of $200 belonging to the special fund subscribed for the purchase of clocks and equipment before mentioned.

The report of Prof. Hough upon the work done at the Observatory during the year, is submitted herewith, and made a part of this report.

Respectfully submitted by the Board of Directors.

C. H. S. MIXER, Sec'y.

REPORT OF THE DIRECTOR

OF THE

DEARBORN OBSERVATORY.

To the Board of Directors of the
Chicago Astronomical Society:

GENTLEMEN: The following brief report will exhibit the nature and amount of the astronomical work carried on at the Dearborn Observatory during the past year.

There has been no material change in its equipment since the last report. The instruments have all been kept in good working order, by making the necessary repairs and adjustments when needed.

The Repsold meridian circle has been used on every clear day or night for time observations, for which purpose upward of 700 transits of standard stars and other objects, were observed with the chronograph.

As heretofore, automatic time signals have been sent daily, from the Observatory to the Western Union Telegraph Company's office, for distribution to the railroads and jewelers.

On the 15th of January, 1881, the Observatory began to furnish standard time to the office of Fire-alarm Telegraph, according to the terms of a contract made by the Directors of the Astronomical Society with the city of Chicago. An insulated line of telegraph wire was subsequently erected connecting the Dearborn Observatory and the Fire-alarm office; since which period automatic time signals have been transmitted.

Two standard clocks have been ordered to be constructed by Howard & Co., Boston, one for the use of the city, and the other for the Observatory. They will be ready for use in a few weeks.

THE EQUATORIAL.

The work with the great equatorial has been mostly confined to the study of special objects and phenomena, for which great optical power, combined with good definition, is desirable.

The planet Jupiter was made a special study during the past year. The first observation was secured on May 6, 1880, and the last on January 30, 1881. During this period the various spots and markings on his disc, were subjected to micrometer measurements whenever practicable. It is readily apparent to any one, who has examined cotemporaneous drawings or sketches made by different observers and telescopes, that they are generally unreliable, unless based on micrometer measurement, and frequently give rise to erroneous deductions with regard to the phenomena in question. We believe the time has passed, when mere estimations or sketches are of value in any department of practical Astronomy. Jupiter presents such a variety of phenomena on his disc, at different times, that it has been accepted as an established fact that his surface is subject to sudden and rapid changes, which may be accomplished in a few days or even a few hours.

The observations made at the Dearborn Observatory during the past two years does not confirm this statement. On the contrary, all minor changes in the markings or spots have been slow and gradual, such as might be produced by the operation of measurable mechanical forces. In fact, the principal features have been permanent, no material change being detected by micrometer measurement.

The following is a summary of the observations on Jupiter:

GREAT RED SPOT.

Longitude,	37 nights	560 measures.
Latitude,	12 "	34 "
Length,	20 "	67 "
Breadth,	10 "	32 "
Position of maj. axis,	5 "	16 "
Total		709 "

EQUATORIAL BELT.

Observed on 26 nights —

Position of the North Edge	87	measures.
Latitude " " "	34	"
Width of the Belt	53	"
Total	174	"

EQUATORIAL WHITE SPOTS.

Observed on 18 nights —

Longitude	240	measures.
Latitude	15	"
Total	255	"

POLAR SPOTS.

Observed on 22 nights —

Longitude	144	measures.
Latitude	40	"
Total	184	"

Being a total of 1,379 micrometer measurements.

From the micrometer measurements for longitude of spots, the equatorial diameter of the planet is deduced on 50 different nights, and from the latitude measures, the polar diameter on 13 nights.

The following deductions have been drawn from these observations.

ROTATION OF JUPITER.

The period of the planet's rotation as obtained by different observers, has varied between $9^h\ 49^m$ and $9^h\ 56^m$. The observations made on the great red spot during the opposition of 1879, gave for the rotation period about $9^h\ 55^m\ 34^s$; being 8 seconds greater than the previously accepted value.

The discussion of our longitude measures on the great red spot, made from September 25, 1879, to January 27, 1881, comprising a period of 490 days, gives for the mean value $9^h\ 55^m\ 35.2^s$.

When the individual observations are compared, however, with this value, there is found to be a well marked maximum displacement of the center of the spot amounting to 1″.4 of arc, indicating that the center gradually oscillated to this extent in longitude, corresponding to an actual displacement on the surface of Jupiter of 3,200 miles.

The observations are all well represented by making the rotation period depend on some function of the time.

The period $9^h\ 55^m\ 33.2^s + 0.18^s \sqrt{t}$ satisfies all the observations with a mean maximum error of 0″.5 of arc. In which the zero epoch is September 25, 1879, and t is the number of days after that date.

This formula gives for the rotation at the date January 27, 1881, $9^h\ 55^m\ 37.2^s$, agreeing essentially will the value deduced directly from the observations made during the two months previous to that date.

The rotation period derived from the observation of polar spots was as follows:

	Latitude.	Longitude.	Interval between extreme observations.	Rotation.
White Spot...	+10″.46	$3^h\ 00^m$	2 months.	$9^h\ 55^m\ 39.3^s$
White " ...	−11″.62	$3^h\ 57^m$	2 "	31.0^s
White " ...	−11″.62	$4^h\ 26^m$	2 "	33.6^s
Black " ...	+10″.40	$0^h\ 00^m$	2 "	31.0^s
Black " ...	+ 9″.70	$2^h\ 22^m$	1 "	40.5^s
Mean of all............................				$9^h\ 55^m\ 35.1^s$

The latitude is simply the measured distance north or south of the Jovian equator, reduced to the mean distance of the planet from the earth. The zero of longitude is the center of the great red spot.

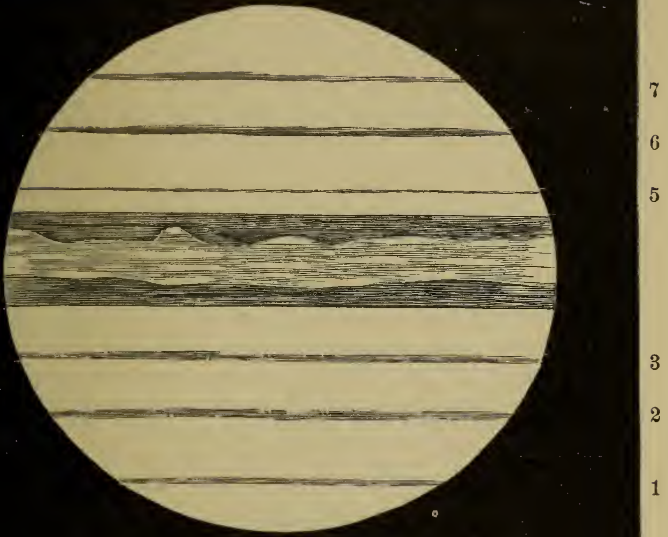
The white spots were egg-shaped, about 1″ of arc in length, and were only visible under favorable atmospheric conditions.

The rotation period derived from the small spots, indicates an average displacement during two months, of 2″ of arc, or 4,600 miles, or an average drift in longitude of nearly 3 miles per hour.

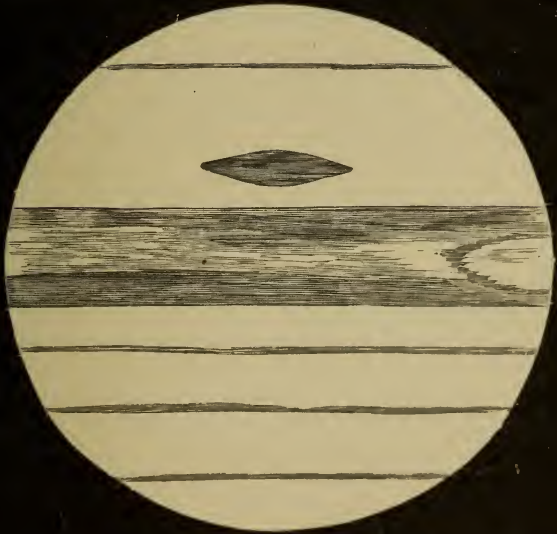
ROTATION FROM EQUATORIAL SPOTS.

From July 8 to October 1, 1880, comprising a period of

JUPITER



6H.-30M. OCT. 21ST. 1879



9H.-22M. OCT. 29TH. 1879

85 days, the longitude of a white spot, between the equatorial belts in latitude $-2''.3$, was observed on 10 nights. The rotation as deduced from this spot was $9^h\ 50^m\ 00.56^s$, representing all the observations within $0''.3$ of arc, showing that the motion, so far as we know, was absolutely uniform. From October 28, 1880, to January 30, 1881, during a period of 94 days, another white spot, in latitude $-2''.8$, and differing 20 deg. in longitude from the first, was observed on 8 nights.

The rotation was $9^h\ 50^m\ 09^s.8$, with uniform motion.

If the great red spot is supposed fixed, then the mean drift of the equatorial spots, would be about 270 miles per hour in the direction of the planet's rotation, or the spot made a complete revolution around the planet in about 42 days.

The approximate diameter of the equatorial white spots was $1''.2$ of arc, or 2,800 miles.

These observations leave the true period of the rotation of Jupiter in a very unsettled condition.

The great red spot was frequently measured to ascertain whether it was subject to any marked change, in position, size or shape.

The following are the mean results for the two oppositions of 1879 and 1880, reduced to the mean distance of the planet from the earth:

	1879.	No. of Obs.	1880.	No. of Obs.
Length, ...	$12''.25$*	9	$11''.55$	20
Breadth, ...	$3''.46$	8	$3''.54$	10
Latitude, ...	$-6''.95$	8	$-7''.14$	12

The position of the major axis of the spot was measured as follows; the numbers indicating the inclination of the axis to Jupiter's equator, as compared with Marth's ephemeris:

1880, July	27	+ 2°.3
" Aug.	6	+ 2°.5
" Sept.	4	+ 2°.9
" Dec.	3	+ 2°.2
1881, Jan.	17	– 0°.8. Definition poor.

---

* Recomputed with the constants of 1880.

These numbers indicate a remarkable degree of permanency with regard to the size, shape and position of the spot, during the two oppositions. Our observations do not warrant the assumption of any considerable change, since September 25, 1879.

The actual size of the object, as seen with our telescope, was as follows:

Length,	29,600 miles.
Breadth,	8,300 "

The smaller telescopes make the approximate length considerably less than the real value.

POLAR BELTS.

During the opposition of 1880, the polar belts were not as sharply defined as during 1879, with the exception of Nos. 2 and 3, the latter of which became very conspicuous. During the month of June, when the planet was at about mean distance, no trace of polar markings could be seen. And it was not until July 4, when the distance was 0.948, that the belts 2 and 3 were barely visible. Markings on the southern hemisphere were first seen on July 24, when the distance of the planet from the earth was 0.888.

The latitude of 2 and 3 was as follows:

	1879.	1880.
No. 2,	+9″.78	+9″.75
No. 3,	+5″.98	+5″.89

Showing that these belts remained without appreciable change of position during the two oppositions.

EQUATORIAL BELT.

The great equatorial belt remained without any material change in size or position, as the following measurements will show:

	1879.	1880.
Latitude N. Edge,	+2″.59	+2″.35
Width..........	6″.77	7″.04

During both years, the position of the north-edge was parallel to Jupiter's equator, as given in Marth's ephemeris.

PHENOMENA.

When a satellite crosses the disc of the planet, it usually disappears in our telescope, when one-fourth to one-third across the disk, and reappears at an equal distance from the preceding limb, proving that the center of the disc is more luminous than the satellite.

In the case of the first satellite, it is sometimes seen to transit as a grayish spot, and remains visible when on the middle of the disc; such a phenomenon was observed on December 10, 1880.

On July 3, 1880, the second satellite during transit, passed almost directly over the center of the great red spot; when it appeared sensibly as bright as when off the disc.

On November 1, 1880, I had the good fortune to witness the transit of the shadow of the second satellite over the center of the red spot, and at the same time, the transit of the shadow of the first satellite over the disc of the planet.

The shadow of the satellite when fully projected on the red spot, was distinctly visible, but not quite as black as the shadow on the disc, proving that the red spot, although much less luminous than the disc, was yet much more luminous than the shadow.

THEORY OF JUPITER.

The generally accepted theory is, that the planet Jupiter is surrounded by a dense atmosphere, that the belts are the solid portions of the planet, and that the minor spots are clouds floating in the atmosphere. It is difficult, if not impossible, to reconcile the known phenomena with any theory yet proposed. But whether there are a sufficient number of well determined facts to form a better one, is doubtful.

Accurate observations are needed on the markings seen at different times on his disc; not sketches and general statements, but suitable micrometer measurements, from which may be deduced the motions and changes taking place on the surface. And until this method is pursued, there is but little hope of solving the problem of his physical constitution.

It has occurred to me, however, that the known phenomena might be explained on the following hypothesis, viz: that the surface of the planet is covered with a liquid semi-incandescent mass; that the belts, the great red spot, and other dark markings, are composed of matter at a lower temperature. The egg-shaped, polar white spots, are openings in the semi-fluid crust. This hypothesis would account for the slow and gradual changes occurring on the surface, which does not seem reasonable on the simple atmospheric theory.

Over the liquid surface, is an atmosphere in which is formed the equatorial white spots, which are of the nature of cloud.

SATELLITES OF URANUS.

Owing to the unfavorable spring weather, observations on Uranus were not possible until April 6, more than a month after opposition. I succeeded, however, in getting a few measures on all four of the satellites.

NEBULA IN THE PLEIADES.

In 1859 a nebula was discovered by Tempel, near the star *Merope*, in the pleiades. During the past twenty years, perhaps more has been written about it than any nebula in the heavens. A number of prominent astronomers failed to see it at all, and those who did see it, described it differently, and placed it in different localities.

In Herschel's general catalogue it is described as follows: Interesting object, bright, very large, irregular figure, variable. Its variability has been denied.

The casual examination of *Merope* in 1879, with the Chicago telescope, failed to show any trace of nebulosity. In view of the fact that it was seen so differently by different persons and telescopes, it was thought desirable to make a thorough examination of the locality of the alleged nebula, to ascertain whether it was visible with our telescope, Mr. S. W. Burnham joining me in this work.

Without going into details, I will simply state that we proved to our own satisfaction that the nebula did not exist, but that the appearances described by different astronomers, was wholly an optical illusion, due to the glow from *Merope* and neighboring stars.

During the year, casual observations were made on binary stars, nebulæ, planets, comets, occultations, etc.

COMPANION OF SIRIUS.

Prof. E. Colbert has computed the following orbit and ephemeris, of the companion to Sirius.

"This star is the first discovered in January, 1862, by the aid of the Chicago Equatorial; and its position was announced four months previously as the result of a calculation by Prof. T. H. Safford, subsequently the First Director of the Dearborn Observatory. It is therefore an object of especial interest to the Chicago Astronomical Society.

The following elements of orbit give apparent position angles and distances noted in subsequent table:

Semi axis major,	8·41 sec.	Eccentricity, 0·58.
Mean motion,	7·26 deg.	Period, 49·6 years.
Inclination,	57·1 deg.	Position of Node, 42·4 deg.

Date of Apastron passage, A.D. 1867·0; giving Node to Periastron, 133·0 degrees, measured in the direction of the star's (retrograde) motion.

[For the apparent orbit, a=7·682 secs; e=0·848; angle between axis and Node line, 9 deg. nearly.]

DATE A.D.	Pos. Angle. Degrees.	App. Dist. Seconds.	DATE. A. D.	Pos. Angle. Degrees.	App. Dist. Seconds.
1862·2	84·1	9·0	1880·2	47·8	10·3
1863·2	81·4	9·35	1881·2	45·55	9·9
1864·2	78·85	9·7	1882·2	43·1	9·45
1865·2	76·45	10·0	1883·2	40·4	8·85
1866·2	74·25	10·3	1884·2	37·25	8·2
1867·2	72·15	10·55	1885·2	33·5	7·4
1868·2	70·1	10·75	1886·2	28·8	6·5
1869·2	68·15	10·95	1887·2	22·4	5·6
1870·2	66·3	11·1	1888·2	12·9	4·3
1871·2	64·45	11·25	1889·2	356·1	3·1
1872·2	62·65	11·35	1890·2	322·2	2·2
1873·2	60·9	11·4	1891·2	273·9	2·3
1874·2	59·1	11·4	1892·2	242·5	3·15
1875·2	57·35	11·35	1893·2	224·6	3·9
1876·2	55·55	11·25	1894·2	211·6	4·4
1877·2	53·7	11·1			
1878·2	51·8	10·9			
1879.2	49·85	10·65			

The curve obtained by comparing the observations intersects the calculated orbit in 1866 and 1878, with a maximum deviation of —0·35 degree in 1871. If both curves be accepted as exact, the difference would be due to the existence of a disturber, with probable period of about 20 years, and position angle about 200° at the beginning of 1881."

OBSERVING CHAIR.

During the past year, in connection with Mr. Burnham, I constructed an observing seat for use with the equatorial, in making micrometer observations.

The complicated, expensive and unwieldy chairs hitherto used with large telescopes require so much time and labor for their manipulation as to render them practically valueless.

I adapted a light sliding seat to an ordinary step-ladder. This seat is held in place by the friction of a small rope wrapped once around a fixed drum, and may be raised or lowered with great ease and expedition. A description with working drawings has been published in the monthly notices of the Royal Astronomical Society, and also reproduced in the *English Mechanic.*

Recently a duplicate of our chair has been constructed for the Washburne Observatory at Madison, Wis.

Mr. S. W. Burnham, as heretofore, has had the use of the great equatorial for double-star observations.

He reports the discovery since May, 1880, of about fifty new double-stars, all of which were measured at least three times. About one-half of the number are close double, not exceeding 1″·5 in distance. Among the more prominent stars, are 9 persei, 5 persei, κ pegasi, γ foracis, and 60 arietis. He also made about 600 measures on previously known double stars.

I regret to announce that the Observatory has lost the valuable services of Mr. Burnham, who for a number of years made use of our great equatorial with such eminent success in double star research. He left the city about April 1, to accept a position in the Washburne Observatory, at Madison, Wis.

The following papers have been furnished for publication: Micrometer observations of the satellites of Uranus during the opposition of 1880.—*Astronomische Nachrichten.*

Ephemeris of the red spot on Jupiter with methods for making observations.—*Astronomical Register.*

Observing seat for the equatorial.—*Monthly Notices, Royal Ast. Soc.*

The nebula in the pleiades.—*Monthly Notices, Royal Ast. Soc.*

As heretofore, the Observatory has been open to special visitors on Tuesday and Thursday evenings of each week.

During the winter term, instruction in practical and theoretical astronomy was given daily, to the senior class of the university.

G. W. Hough,
Director.

Chicago, May, 1881.

REMOTE STORAGE

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# ANNUAL REPORT

OF THE

BOARD OF DIRECTORS

OF THE

Chicago Astronomical Society

TOGETHER WITH THE

REPORT OF THE DIRECTOR

OF THE

DEARBORN OBSERVATORY,

1882.

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Prof. G. W. Hough.

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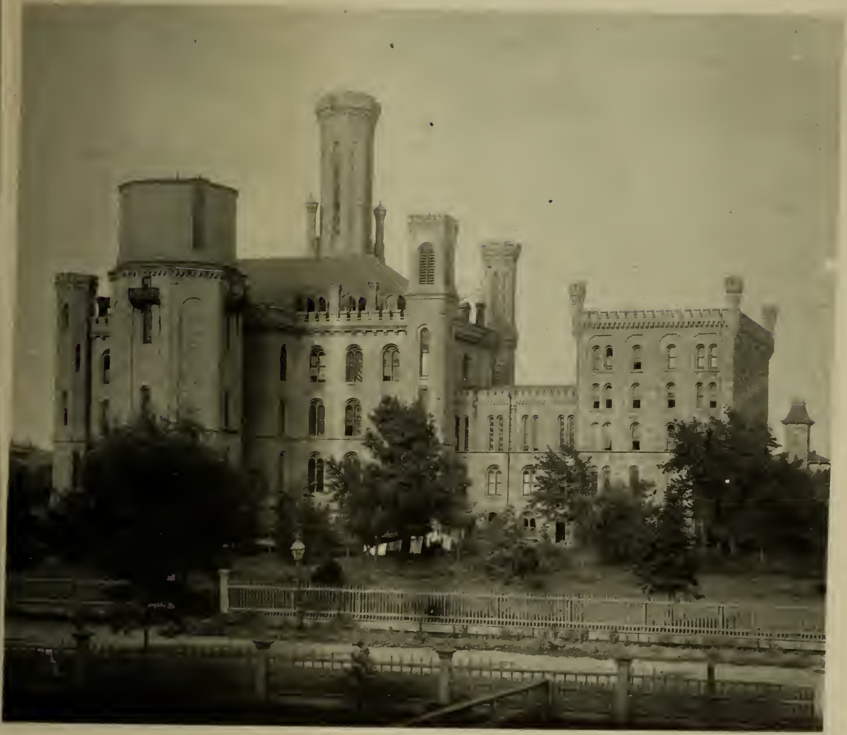

REAR VIEW OF THE CHICAGO UNIVERSITY,

SHOWING THE TOWER OF THE DEARBORN OBSERVATORY.

520.6
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1882

REPORT.

Annual Report of the Board of Directors
to the Chicago Astronomical Society:

Your directors take pleasure in reporting a very considerable improvement during the past year in the general condition of the Society's affairs.

The prompt response by some of its members and friends at the beginning of the year to the appeal for funds with which to pay for the new clocks and other equipments for time service, and the successful performance of that service, with the compensation therefor, have contributed greatly to this result.

It is known to the members of the Society that the Union Mutual Life Insurance Company has commenced proceedings against the Chicago University for foreclosure on a mortgage under which an indebtedness of about $150,000 is claimed.

This mortgage was made subsequently to the agreement made with the Astronomical Society by the University, under which the Society built and equipped its observatory, and while the Society was in actual possession and occupancy of Dearborn tower and appurtenances.

The facts in the case show, as we are advised, that the Insurance Company in consequence of such possession and occupancy, had legal notice of the rights of this Society to the perpetual use of the premises occupied by it, and these rights are defended and asserted by a bill of interpleader filed by this Society in connection with said foreclosure suit.

The Society is put to no expense in this litigation, as the

University is bound to protect it, and Messrs. Willard & Driggs, the solicitors of the University, have, without charge to the Society, prepared and filed all the papers in the case, and they and Hon. Thomas Hoyne are attending to the interests of the Society under the direction of Mr. Scammon.

The Society has during the past two years printed condensed reports of work done at your Observatory, but has not been free to incur such an expense as would have done fuller justice to the work performed, and to astronomical science; and your Directors recommend that the friends of the Society be asked to aid in printing a more complete report of that of the past year.

The Treasurer reports a balance on hand to the credit of the general fund of $1,216.11, and to the credit of a new subscription fund for the present year, the sum of $250.

Under a renewal of the contract with the city authorities, the time service will be continued through the current year.

The following gentlemen have become life members of the Society since the last annual meeting: John H. Dwight, Charles A. Mair, Norman B. Ream, Peter McGeoch, William C. Seipp.

Your Directors offer the results of the year as evidence that the Society needs only the hearty and active interest of its members and friends to become an institution in the work of which our city may take pride.

Prof. G. W. Hough, the Director in charge, has prepared a summary of his observations and studies during the year, and those of other gentlemen who have used your instruments, which is herewith submitted and made a part of this report.

Respectfully submitted by the Board of Directors.

C. H. S. MIXER,
Secretary.

REPORT OF THE DIRECTOR

OF THE

DEARBORN OBSERVATORY.

To the Board of Directors of the
Chicago Astronomical Society:

GENTLEMEN: The following brief report will exhibit the nature and amount of the astronomical work carried on at the Dearborn Observatory during the past year.

The instruments have all been kept in good working order, by making the necessary repairs and adjustments when needed.

The two standard clocks, ordered to be constructed by Howard & Co., Boston, were received during the months of June and July last. One was placed in the City Fire-Alarm office, for the use of the city in connection with the time service. And the other was mounted at the Observatory, for keeping standard time.

The fire-alarm clock has been kept as nearly correct as practicable, the error rarely exceeding two seconds from true time. During the past four months, through the courtesy of Prof. Barrett, the superintendent, the error of this clock has been telegraphed to the Observatory daily.

The automatic time signals for the city have been transmitted continuously throughout the year, with the exception of an intermission of a couple of hours last summer, when the relay at the Observatory was temporarily disabled during a thunder-storm.

The standard clock at the Observatory has maintained a satisfactory rate; but it might be made to perform still better by inclosing it in a closet which would protect it from sudden changes of temperature.

The going of the mean-time clock has been greatly improved by increasing the driving weight from one and one-half pounds to four and one-half pounds; but in order to make it first-class, it should be re-compensated and mounted on an iron shelf.

During the year, the time signals have been usually correct within two-tenths of a second, and the accumulated error has rarely amounted to one-half second; so that our time-service will now compare favorably with the best systems elsewhere.

As heretofore, automatic time signals have been sent daily from the Observatory to the Western Union Telegraph Company's office, for distribution to the railroads and jewelers.

The Repsold meridian circle has been used on every clear day or night for time observations, for which purpose about 600 standard stars and other objects were observed on five wires, and the times of transit recorded on the chronograph.

This instrument was also used for observing the position of the great comet of 1881 on the meridian, at the lower culmination.

From June 30 to July 14, the comet was observed on nine nights for right ascension and declination.

THE EQUATORIAL.

The work with the great equatorial, as heretofore, has been mostly confined to the study of special objects and phenomena, for which great optical power, combined with good definition, is desirable.

The following objects were specially studied:

(1) The Great Comet of 1881.
(2) The planet Jupiter.
(3) The Satellites of Uranus.
(4) Difficult double stars.

THE GREAT COMET OF 1881.

Micrometer measures of the nucleus and envelope of the great comet of 1881, together with sketches showing the changes taking place from day to day, were made by Prof. Colbert and myself on eight nights, between June 23 and July 14.

These sketches showed some curious changes in the shape of the envelope about the nucleus; but no division of the nucleus, as has been alleged, was observed during this period.

If such a division really took place, it must have continued only a few hours. It seems possible, therefore, that the phenomenon in question was simply occasioned by the want of sufficient optical power to see its real character.

Prof. Colbert also made a drawing of the nucleus and envelope on June 23, showing the peculiar formation of the head and surrounding envelopes. This drawing was published in the daily "Tribune." He also made the earliest announcement of the distance of the comet from the earth.

THE PLANET JUPITER.

The various spots and markings on the planet Jupiter, as heretofore, have been carefully studied by means of micrometer measurements, accompanied by eye sketches when necessary. The work on this planet during the past three oppositions enables us to decide definitely on some points regarding the phenomena exhibited on his disc; but the actual condition of his surface cannot yet be regarded as fully ascertained. The experience, however, of the past three years has shown conclusively that direct micrometer measurement is infinitely superior to any method of estimation. In attempting to reconcile the various phenomena alleged to have been seen on his disc, the greatest difficulty exists in determining what is real and what is imaginary. Cotemporaneous sketches by different persons, or even by the same observer, show such marked discrepancies that they are of but little use in ascertaining suspected changes.

Our observations during the past three years confirm the statement heretofore made, that the changes taking place on the disc are slow and gradual; in fact, directly contrary to the doctrine taught in text-books and the history of astronomy.

It seems probable, that when the subject is more carefully studied, the phenomena seen on the disk of Jupiter will be found to be periodical, in a manner analogous to that exhibited on the surface of the Sun. It seems probable, also, that some of the markings are comparatively permanent in locality.

The hypothesis presented in last year's report, that the surface of the planet is liquid, or in a plastic condition, seems to accommodate known phenomena better than any other yet proposed.

The following is a summary of the observations on Jupiter:

GREAT RED SPOT.

Longitude	38	nights;	484	measures
Latitude	12	"	25	"
Length	13	"	39	"
Breadth	4	"	12	"
Position of major axis	3	"	12	"
Total			572	"

EQUATORIAL BELT.

Observed on twenty-four nights:

Position of the north edge	60	measures
Latitude	15	"
Width	30	"
Total	105	"

EQUATORIAL WHITE SPOTS.

Observed on thirty-two nights:

Longitude	320	measures
Latitude	18	"
Total	328	"

POLAR SPOTS, AND OTHER MARKINGS.

Observed on twenty-seven nights:

Longitude	180	measures
Latitude	60	"
Total	240	"

Being a total of 1,255 micrometer measurements.

From the micrometer measurements for longitude of spots, the equatorial diameter of the planet is deduced on fifty-six different nights, and from the latitude measures, the polar diameter on thirty nights.

The following deductions have been drawn from these observations:

ROTATION OF JUPITER.

The observations made during 1879 and 1880 showed that the great red spot was retrograding with an accelerated velocity. This drifting has continued up to the present time, and with such remarkable uniformity that the position of the spot at any future period can be very accurately computed.

The "mean" rotation period, from the observations of 1879 and 1880, was found to be $9^h\ 55^m\ 33^s.2+0^s.09\sqrt{t}$, in which t represents the number of days after September 25, 1879. This formula was essentially correct for the past opposition; but it was found that all the observations could be fairly represented by making the rotation period vary directly with the time, instead of the square root of the time.

The "mean" period as deduced on this hypothesis was $9^h\ 55^m\ 34^s.0+t\times 0^s.00209$, or $9^h\ 55^m\ 35^s.9$ for the "mean" period between September 25, 1879, and March 29, 1882, comprising 916 days, or 2,214 rotations of the planet. The actual period on March 29, 1882, from the formula is $9^h\ 55^m\ 37^s.8$

From these figures it appears that the apparent rotation period has increased about four seconds since the opposition of 1879, indicating a total drift of the red spot in longitude of 40,000 miles; being about 10,000 for the first year, and 30,000 for the second year. These observations prove that the red spot is not the solid portion of the planet, as has been held by a number of astronomers. One of the most curious features of this interesting object is its stability. Here we have an immense floating island, 29,600 miles in length by 8,300 miles in breadth, which has maintained its shape and size, without material change, during more than three years.

The following mean results will show what probable changes have occurred. The numbers are all reduced to the mean distance of the planet from the earth:

	1879.	No. Obs.	1880.	No. Obs.	1881.	No. Obs.
Length....	12″.25	9	11″.55	20	11″.30	13
Breadth...	3″.46	8	3″.54	10	3″.66	4
Latitude ..	−6″.95	8	−7″.14	12	−7″.40	10

The position of the major axis of the spot was as follows:

		No. Obs.
1880................	+2°.2	5
1881................	+1°.8	3

It appears from these numbers, that between the oppositions of 1880 and 1881 the length has diminished 0″.25, or 580 miles; the breadth has increased 0″.12, or 290 miles; and that it has drifted in latitude 0″.26, or 600 miles.

The position of its major axis was essentially the same, and so far as the eye could judge the elliptical outline was the same in 1882 as in 1879. The color, also, has not materially altered. It has been recently stated by some astronomers that the spot was fading. If such be the case, I have failed to recognize the fact. On February 2, 1882, the seeing was good, when the color was found to be the same as formerly, viz, a light pink.

The color, both of the spot and belts, varies at different times, depending on the condition of the seeing. The spot and belts generally appear as a dull brick color, but on rare occasions the pink tint is very marked, especially in the red spot.

POLAR BELTS.

During the opposition of 1881 the principal polar belts were Nos. 2, 3, and 6.

The belts 2 and 3 during the past three years have remained in essentially the same latitude, as the following numbers will show:

	1879.	1880.	1881.
No. 2......	+ 9.78	+ 9.75	+ 9.11
No. 3......	+ 5.98	+ 5.89	+ 5.87

The most noticeable change has taken place in the appearance of belt No. 3. During 1879 it was not conspicuous, but it gradually increased in width and distinctness during 1880, until it reached a width of 2″.5 during the past opposition. The color, which during 1879 and 1880 was dark brown, appeared in 1881 reddish, or very similar to that of the equatorial belt.

EQUATORIAL BELT.

The great equatorial belt remained without any material change in the position of the north and south margins; but there was less dark matter between the two margins of the belt than in 1879 and 1880.

The following measurements will show what changes have taken place:

	1879.	No. Obs.	1880.	No. Obs.	1881.	No. Obs.
Latitude, north edge	+ 2″.59	10	+ 2″.33	11	+ 2″.16	7
Width	6 .77	9	7 .04	14	6″.91	10

These numbers indicate a possible displacement in latitude of 0″.43 from 1879 to 1881.

The direction of the south edge of the belt was nearly parallel with Jupiter's equator, as given in Marth's Ephemeris. The following was the inclination observed:

	Inclination.	No. Observations.
1879..............	− 0°.01	18
1880..............	+ 0°.09	24
1881..............	+ 0°.74	20

The north edge of this belt is slightly concave.

ELLIPTICAL WHITE SPOTS.

The small, oval, white spots, a few of which made their appearance in 1880, were more numerous during the past opposition; but with the exception of two, directly south of the great red spot, they were exceedingly difficult, and could only be measured when the seeing was unusually good.

The observation of these spots has an important bearing on the rotation of different portions of the surface of the planet, as well as on its condition.

A single spot was observed on belt 3, in latitude $+ 4''.59$ and longitude $+ 4^h$, on November 1 and December 14. Unfortunately, these times differ by forty-three days, and as no other observation was secured, the whole number of rotations is in doubt. The apparent rotation period, therefore, may be $9^h\ 55^m\ 31^s.9$, or $9^h\ 49^m\ 51^s.6$; the former being the most probable.

On belt No. 6, in latitude $- 9''.6$ to $- 12''.6$, and longitude $+ 2^h.8$ to $+ 5^h.8$, no less than eight different spots were observed. They were not absolutely fixed among themselves or with reference to the great red spot, but indicated, however, a rotation period not differing greatly from that of the red spot. These results are in harmony with the observations of last year.

Two white spots, south of the great red spot, in latitude $- 9''.63$, were systematically observed during a period of three months, from November 21, 1881, to February 23, 1882.

The following figures will show the motion of these spots during the above-named period:

Date.	Difference of longitude between the following spot and the center of the great red spot.
November 22, 1881........	$+ 25^m.5$
November 24, 1881........	$+ 26^m.1$
December 1, 1881	$+ 24^m.4$
December 6, 1881	$+ 23^m.3$
December 23, 1881........	$+ 12^m.5$
December 28, 1881........	$+ 6^m.6$
January 9, 1882	$- 5^m.4$
February 4, 1882..........	$- 29^m.4$
February 23, 1882.........	$- 42^m.8$

These numbers indicate that it was at rest, relative to the red spot, from November 22 to December 6, and that subsequently it began to drift in the direction of the planet's rotation; the total drift being about 41°. During the last two months the average drift was at the rate of fifteen miles per hour.

The difference of longitude between the preceding and following white spots was as follows:

Date.	Diff. of long.
December 1, 1881	$60^m.0$
December 28, 1881	$42^m.0$
January 9, 1882	$46^m.3$
February 4, 1882	$43^m.0$
February 23, 1882	$33^m.5$

These numbers indicate that the two spots did not retain the same relative position in longitude with respect to each other.

The observations of the small white spots, during 1880 and 1881, prove that the whole surface of the planet, outside the margin of the equatorial belt, rotates with nearly the same rate. Also that these minute spots are not absolutely fixed in longitude, but may have a slow direct or retrograde motion. They are *not*, therefore, the tops of mountains, as a recent writer has suggested.

EQUATORIAL WHITE SPOTS.

The white spots which were visible between the margins of the great equatorial belt in 1879, have continued during 1880 and 1881.

There are two principal spots, differing in longitude about 15°, and in latitude about 1″.

Sometimes they are both visible, but usually only one. Occasionally a third spot is seen; the three being nearly equidistant from each other. During the past opposition, the principal spot is probably the same as that observed from October 28, 1880.

The first observation, during the past opposition, was secured on July 22, 1881, and the last on March 31, 1882, comprising a period of two hundred and fifty-two days, or more than eight months. The approximate rotation period for this spot was $9^h\ 50^m\ 09^s.8$, or the same as for the second spot observed during 1880.

These numbers indicate that the equatorial white spots drift in the direction of the planet's rotation, at the rate of two hundred and sixty miles per hour, and consequently make a complete revolution in about forty-five days.

From observations on other small white spots, as well as on dark markings near the equator, it is probable that the matter in the equatorial regions constantly drifts in the direction of the planet's rotation; and it seems probable that the rate of this drift depends on the latitude.

Some of the observations made during the past year, led us to suspect that the great equatorial belt partook of this drift-motion, but others, on the contrary, seemed to indicate that it was fixed relatively to the great red spot.

A peculiar spur, which appeared to be connected with the south margin of the equatorial belt, was seen a number of times in 1880, and its longitude, from a single measure on September 9, 1880, was $+19^m.0$. It was seen again on December 1, 6, etc., 1881, and its longitude was found to be $+24^m.4$ and $+23^m.3$, or essentially the same as for the previous year. If the spur is joined to the belt, then its rotation is the same as for the red spot.

From what has already been said, you will infer that the true rotation of the planet Jupiter is yet unknown. It is possible, however, that the rotation of the surface varies with the latitude in a manner analogous to that of the sun's surface.

The explanation of the phenomena seen on this planet is a problem of great difficulty, which can only be solved by persistent and continuous observation.

SATELLITES OF URANUS.

The unfavorable observing weather which we have in this climate during February and March is a great drawback in making observations on such difficult objects as the inner satellites of Uranus.

The following is a summary of the observations:

Ariel	2 nights
Umbriel	3 "
Titania	6 "
Oberon	8 "

DOUBLE STARS.

When Mr. S. W. Burnham left the Observatory to go to Madison, I began the observation of difficult double stars, more especially binary systems, as I thought it proper this kind of work should not be entirely neglected. Owing, however, to the fact that my special work has been in other directions, not very much time could be given to it. About 250 micrometer measures were made, however, including 9 of the companions of Sirius. There were also discovered about 60 difficult double stars not found in the catalogues. Among these there were two quadruple systems and one naked-eye star, with a very minute companion. They may be classified as follows:

7 less than 1″ distance.
10 from 1″ to 2″ distance.
37 from 2″ to 5″ distance.
6 over 5″ distance.

The Observatory, as usual, has been open to members of the Astronomical Society on Thursday evenings, and by special arrangement I have on a few evenings admitted classes in astronomy from the city high schools and elsewhere.

During the winter term, instruction in practical and theoretical astronomy was given to the senior class of the University.

Mr. S. W. Burnham, who was absent during the past summer at the Washburne Observatory, has returned to the city, and has resumed the observation of double stars with the great refractor. He reports:

The measurement of newly discovered double stars, and the preparation for publication of a catalogue of 151 double stars discovered here during the past three years; also a compilation of all his star observations made during the same period, comprising about 2,500 measures.

G. W. HOUGH,
Director.

Chicago, June, 1882.

APPENDIX A.

HISTORICAL REVIEW OF THE CHICAGO ASTRONOMICAL SOCIETY.

The Hon. J. Y. Scammon having resigned the office of President of this Society, which he has held from its organization to the present time, the Directors deem it a fit occasion for presenting a brief review of the Society's history.

In December, 1862, a movement was made, in connection with a lecture on Astronomy, to procure subscriptions for the establishment of an Astronomical Observatory in Chicago, and a committee was appointed for that purpose. A member of the committee wrote immediately to Mr. Alvan Clark of Cambidge, Mass., and learned by letter from him, dated the 19th of the same month, that he had on his hands a telescope which he had made for the University of Mississippi, but which the opening of the war had prevented that institution from taking. This glass had a clear aperture of 18½ inches and a focal length of 23 feet. The two largest achromatic telescopes in existence previous to that time were those at Harvard College, in this country, and at Pulkova, in Russia. Each of these instruments has an aperture of about 15 inches.

The efforts to raise money for the establishment of an Observatory were measurably successful, and in January, 1863, Hon. Thomas Hoyne was deputed to visit Cambridge and negotiate for the purchase of the great Clark Telescope. His arrival at Cambridge was exceedingly opportune, for he found that negotiations were going forward on the very day of his arrival for the purchase of the instrument in the interest of another Observatory. Mr. Hoyne closed a contract for its purchase without loss of time, and paid the first installment of $1,500. The whole cost of the instrument was $11,100 for the object glass, and $7,000 for the mounting.

The organization of the Chicago Astronomical Society* took place in November, 1863.

The first Board of Directors was composed of—

J. Y. Scammon,
Thomas Hoyne,
W. H. Wells,
E. B. McCagg,
A. H. Mixer,
J. H. Woodworth,
J. C. Burroughs,
J. K. Pollard,
T. B. Bryan.

The first officers chosen were J. Y. Scammon, President, W. H. Wells and J. H. Woodworth, Vice-Presidents, Thomas Hoyne, Secretary, and D. J. Ely, Treasurer.

The purchase of a telescope made it necessary to erect a tower on which to mount it, and this required a considerably larger outlay of money than the purchase of the instrument itself. The entire expense of this important work was undertaken by a single individual, Hon. J. Y. Scammon, whose munificence had often been manifested before in connection with various public and private enterprises. Under a contract between the Chicago University and this Society, an arrangement was made for the establishment of the Observatory on the grounds of that institution. The tower was erected by Mr. Scammon on the west side of the University building, with a revolving dome about ninety feet in height. The telescope was placed in position in May, 1864.

The first Director of the Dearborn Observatory was Prof. Truman H. Safford, who had previously been engaged as assistant at the Harvard Observatory.

During the first three years, the Director devoted most of his time to the observation of nebulæ, discovering about one hundred not previously known.

In 1868, Walter S. Gurnee, of New York, formerly Mayor of Chicago, donated $5,000 to the Society for the purchase of a Meridian Circle, and from that time till the great fire of 1871, Prof. Safford was engaged most of the time in a series of star observations, in connection with other astronomers at the principal observatories of the world, for the great catalogue of the German Astronomical Society. The share allotted to the Dearborn Observatory was the zone between the 35th and 40th degrees of northern declination. About two-fifths of the work had been completed at the date of the fire.

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*The early records of the Society were destroyed by the fire of 1871, and the record here given of its organization is copied from the Report of Secretary Hoyne at the meeting in April, 1874.

In 1870, Mr. Elias Colbert was appointed Assistant Director of the Observatory, and his services were of great value to the Society, though he received no compensation for them. It was mainly through his efforts that money was raised to purchase a tower clock and place the Observatory in communication with the Court House bell.

Previous to the great fire, the salary of Prof. Safford was paid entirely by Mr. Scammon. The paralysis caused by the fire deprived Prof. Safford of his support here, and he accepted a position in another field of labor.

In 1874 the Observatory was placed in charge of Mr. Colbert, and remained in his care during the next five years. The dome had become practically useless, and Mr. Colbert raised a subscription for rebuilding it. He also made such observations as his time would allow, and revived the system of time signals that had been commenced before the fire. He arranged for furnishing time by electric communication with the Board of Trade, the Western Union Telegraph Co., the City Fire Alarm Telegraph, and a considerable number of Railroad Companies and jewelers. For these services, Mr. Colbert declined, as before, to receive any compensation.

During this period, Mr. S. W. Burnham made important use of the Observatory in prosecuting his observations upon double stars, of which notices were published in the scientific journals of this country and of Europe.

At the request of the Astronomical Society, Mr. Colbert, Superintendent of the Observatory, arranged an expedition to Denver, Colorado, for the purpose of observing the Solar Eclipse of July 29, 1878. He was accompanied in this undertaking by Prof. G. W. Hough, Dr. Lewis Swift, of Rochester, N. Y., Mr. A. C. Thomas, of this city, and others. The observations were made with great care and exactness, and with highly satisfactory results. It was during these observations that Dr. Swift made his supposed discovery of the planet Vulcan within the orbit of Mercury.

In May, 1879, Prof. G. W. Hough, formerly Director of the Dudley Observatory, at Albany, N. Y., was elected Director of the Dearborn Observatory.

Prof. Hough brought to the Society an experience of many years in making astronomical observations, and his labors here have brought the Dearborn Observatory into special prominence among the leading observatories of the world. His observations on the planet Jupiter, in which he has been assisted by Mr. Colbert, have been recognized as a valuable contribution to Astronomical Science.

Mr. S. W. Burnham has continued the use of the Great Equatorial in his special work of double star observations.

At a recent meeting of the Directors of the Astronomical Society, the Hon. J. Y. Scammon, President of the Society, tendered his resignation, and the Directors recorded their high appreciation of his services in the following language:—

"The Hon. J. Y. Scammon having resigned the office of President of the Chicago Astronomical Society, which office he has held from the organization of the Society in 1862 to the present time, the Directors take this occasion to express their sense of obligation for his untiring interest in the success of the Dearborn Observatory, and for the munificent benefactions he has bestowed upon it.

It is to Mr. Scammon that the Society is indebted for the tower of the Observatory, which he furnished the means to erect at a cost of about $30,000.

Mr. Scammon also made a generous contribution toward the purchase of the Great Refractor, and in the early history of the Society the salary of the Director was for a considerable period paid entirely by the same liberal hand.

Whenever a history of Chicago shall be written in which justice shall be done to those who have made our city what it is, then will the name of J. Y. Scammon be found to occupy an honored place in the records of those whose benefactions have contributed most to the growth and prosperity of the city and its institutions."

APPENDIX B.

Observations on the Planet Jupiter, Made with the 18½ Inch Clark Refractor, at the Dearborn Observatory.

The following observations furnished the time of transit of the center of the great red spot, or other markings, over the meridian of ♃, perpendicular to his equator and bisecting the illuminated disc. They aim to fix with considerable precision the longitude, latitude, size and position of the various spots and markings seen on the disc.

The observations were all made with the parallel wire micrometer of the 18½ inch Clark refractor. During the opposition of 1879, a few of the early measures were referred to only *one* limb of the planet, a method not susceptible of the greatest precision, owing to the uncertain effect of irradiation, due to poor definition or other causes. In all subsequent observations, however, both limbs were used, and the measures combined in such a manner as to entirely eliminate this source of error.

For ascertaining the time of transit over the central meridian, the method of observation was as follows:

The micrometer wires were first set perpendicular to the equator of ♃; one wire was then made to bisect the *apparent* center of the red-spot and the other was placed tangent to the preceding limb of the planet. After two readings in this position, the times being noted to the nearest tenth of a minute, both wires were carried across the disc and one was placed tangent to the following limb and the other made to bisect the red-spot. One-half the difference of the micrometer readings, from a consecutive pair of measures, was equal to the distance of the *apparent* center of the red-spot from the central meridian, at the mean of the times.

The following example is taken from the observing note book:

February 9, 1882.

APPARENT CENTER OF RED-SPOT.

	M. T.	Prec. Limb.	M. T.	Foll. Limb.
	$7^h\ 31^m.3$	$48^{rev}.03$	$7^h\ 29^m.7$	$48^{rev}.335$
	32 .2	.02	30 .3	.325
Mean	7 31 .7	48 .025	7 30 .0	48 .330
				48 .025

$t = 7^h\ 30^m.8$
cor. for watch $+0\ .6$
$\triangle\ t + 9\ .3$
$T = 7\ 40\ .7$

$2\triangle = 0\ .305$
$\triangle = 0\ .152$
$\triangle = +1''.74$
M.D. $= +1''.67$

Usually four sets of measures similar to the above were made for longitude, but during a portion of the opposition of 1880, a much larger number were taken to ascertain whether measures made when the spot was near the limb of the planet were as reliable as when it was near the center of disc.

It appears from these observations that no appreciable error was introduced when the spot was observed within one hour of the central meridian.

As the *apparent* center of the red-spot does not coincide with the true center, except when seen on the central meridian, it is necessary to know its length and latitude, in order properly to reduce the observations.

The following constants and formulæ were used, all of which refer to the mean distance of the planet from the Earth:

CONSTANTS.

♃'s Equatorial semi-diameter	19″.48
" Polar " "	18″.30
Latitude of red-spot	− 7″.14
Logarithm D	1.2538
L	11″.61
V	37°.8

These constants were derived from the observations made in 1880.

l = Observed length of spot in seconds of arc.

L = Length of the chord when on the central meridian.

V = The difference of longitude of the two ends of the spot.

D = Radius of parallel of the center of spot.

h = difference of longitude of the *apparent* center of the spot and ♃'s central meridian.

h_0 = difference of longitude of the *true* center of the spot and ♃'s central meridian.

m_0 = observed distance of the *apparent* center of the spot from ♃'s central meridian.

Δt = time, in minutes, from the central meridian.

$\Delta t = \dfrac{h_0}{0^\circ.6047}$ for the great red-spot and polar spots.

$\Delta t = \dfrac{h}{0^\circ.610}$ for equatorial white spot.

$$D \sin (h_0 - \tfrac{1}{2} V) = m - \tfrac{1}{2} l.$$

$$D \sin (h_0 + \tfrac{1}{2} V) = m + \tfrac{1}{2} l.$$

$$L = 2 D \sin \tfrac{1}{2} V.$$

$$L = \frac{l}{\cos h_0}, \text{ approximately.}$$

The labor of reduction was very much shortened by forming tables of the values of h_0 and Δt for the great red spot and equatorial white spots, with m as the argument.

For the reduction of all other spots, when the length was inappreciable, l and V were made equal to zero, and the formula was $m = D \sin h$.

D = radius of the parallel for the spot observed.

In the table of observations

t = mean of the times for a pair of measures.

m = distance from ♃'s central meridian reduced to mean distance.

Δt = reduction to central meridian.

T = deduced time of transit over ♃'s central meridian.

R = reduction to the zero epoch, September 25, 1879. It includes the following corrections:

1. Aberration time.
2. Equinox time.
3. Annual parallax.
4. Defective illumination.

The aberration and longitude from equinox were computed for every ten days. The annual parallax and defective illumination have been derived from Marth's Ephemerides, published in the "Monthly Notices," Royal Astronomical Society.

The discussion of the observations made on 31 days, comprising 122 sets of measures, from June to December, 1880, gave for the mean error of a single pair of measures ± 0.9 minute, and for the average mean probable error for any day, ± 0.4 minute, on the observed time of transit of the center of the red spot over the central meridian.

It may be inferred from these results that the use of a micrometer is infinitely preferable to any method of estimation.

A single pair of micrometer readings, when the spot is wholly on the disc, will give a more accurate value for the time of transit over the central meridian than any system of estimation, either with or without micrometer wires. By direct measurement there is no reason to believe that there is any appreciable constant error depending on the hour angle of the planet, as Schmidt has shown to be the case for eye estimates.

GREAT RED SPOT, ♃.

Date.	t	m	Δt	T	R	Remarks.
1879	H M	″	M	H M	H M	
Sept. 25 ..	10 51.6	+ 6.23	+36.0	11 27.6	+ 00.0	One limb (2)
Oct. 5	9 38.9	+ 0.33	+ 1.8	9 40.7	+ 00.0	Observed by Prof. Colbert; one limb and end
Oct. 10 ...	8 19.7	+ 4.82	+27.6	8 47.3		One limb
"	9 26.4	− 6.04	−34.8	51.6		
			Mean	8 49.5	+ 00.3	
Oct. 14 ...	10 52.5	+11.54	+71.0	12 03.5	+ 00.4	One limb and end
Oct. 15 ...	8 01.0	− 0.33	− 1.8	7 59.2	+ 00.4	
Oct. 29 ...	8 56.2	+ 5.50	+31.6	9 27.8		
"	58.6	+ 4.76	+27.2	25.8		
"	9 24.0	+ 0.84	+ 4.7	28.7		
			Mean	9 27.4	− 00.7	
1880						
Feb. 10...	5 23.4	+ 1.18	+ 6.6	5 30.0	− 35.7	
May 6....	16 45.6	− 2.09	−11.8	16 33.8	−1 07.3	Planet low, daylight (approximate)
June 9....	14 56.8	− 2.24	−12.5	14 44.3		
"	15 10.4	− 4.92	−27.7	42.7		
			Mean	14 43.5	−1 14.1	
June 16...	15 17.6	+ 1.54	+ 8.8	15 26.4		
"	30.7	− 0.25	− 1.3	29.4		
"	34.9	− 1.08	− 6.2	28.7		
"	39.4	− 2.06	−11.6	27.8		
			Mean	15 28.1	−1 15.1	
July 3....	13 59.5	+ 4.96	+28.4	14 27.9		
"	14 06.8	+ 4.11	+23.2	30.0		
"	31.2	+ 0.02	+ 0.1	31.3		
"	15 16.6	− 7.82	−46.0	30.6		
			Mean	14 30 0	−1 16.6	
July 5....	15 33.9	+ 5.52	+31.4	16 05.3		
"	41.6	+ 4.47	+25.2	06.8		
"	58.4	+ 1.52	+ 8.5	06.9		
"	16 05.8	+ 0.10	+ 0 6	06.4		
			Mean	16 06.4	−1 16.8	
July 8....	13 44.9	− 1.53	− 8.6	13 36.3		
"	50.9	− 2.64	−14.8	36.1		
			Mean	13 36.2	−1 16.8	

Date.	t	m	Δt	T	R	Remarks.
1880	H M	"	M	H M	H M	
July 15	14 08.3	+2.01	+11.2	14 19.5		
"	15.4	+0.62	+ 3.5	18.9		
"	23.1	−0.42	− 2.3	20.8		
			Mean	14 19.7	−1 16.8	
July 20	13 14.8	+1.60	+ 9.0	13 23.8		
"	21.5	+0.70	+ 3.9	25.4		
"	41.3	−2.89	−16.2	25.1		
			Mean	13 24.8	−1 16.9	
July 22	14 41.4	+3.96	+22.3	15 03.7		
"	54.4	+1.84	+10.3	04.7		
"	15 04.9	−0.21	− 1.2	03.7		
"	14.8	−2.04	−11.4	03.4		
			Mean	15 03.9	−1 16.9	
July 27	13 38.9	+5.32	+30.2	14 09.1		
"	52.6	+3.50	+19.7	12.3		
"	14 22.3	−1.84	−10.4	11.9		
			Mean	14 11.1	−1 16.7	
July 29	15 48.8	+0.21	+ 1.2	15 50.0		
"	16 03.2	−2.61	−14.6	48.6		
"	08.1	−3.31	−18.7	49.4		
			Mean	15 49.3	−1 16.6	
Aug. 3	14 41.9	+2.75	+15.4	14 57.3		
"	47.3	+1.71	+ 9.5	56.8		
"	15 01.7	−0.78	− 4.3	57.4		
			Mean	14 57.2	−1 16.3	
Aug. 5	16 07.4	+4.83	+27.3	16 34.7		
"	14.1	+3.70	+20.8	34.9		
"	19.2	+2.85	+16.0	35.2		
"	28.5	+1.33	+ 7.4	35.9		
"	46.7	−2.05	−11.4	35.3		
			Mean	16 35.2	−1 16.2	
Aug. 6	12 29.9	−0.70	− 3.9	12 26.0		
"	34.6	−1.46	− 8.2	26.4		
			Mean	12 26.2	−1 16.1	
Aug. 11	11 58.8	−4.20	−23.7	11 35.1		
"	12 10.6	−6.80	−39.1	31.5		
"	16.7	−7.14	−41.1	35.6		
			Mean	11 34.1	−1 15.6	

Date.	t	m	Δ t	T	R	Remarks.
1880	H M	"	M	H M	H M	
Sept. 4....	11 11.3	+0.89	+ 5.0	11 16.3		
"	15.7	−0.18	− 1.0	14 7		
"	19.4	−0.80	-- 4.4	15.0	−1 11.8	
			Mean	11 15.3	−1 11.8	
Sept. 6....	12 52.5	−0.36	− 2.0	12 50.5		
"	55.9	−0.38	− 2.1	53 8		
"	13 02.0	−1.59	− 8.9	53.1		
			Mean	12 52.5	−1 11.4	
Sept. 9....	10 15.3	+0.81	+ 4.5	10 19.8		
"	18.9	+0.20	+ 1.1	20.0		
"	21.8	−0.09	− 0.5	21.3		
"	25.8	−0.35	- 1.9	23.9		
			Mean	10 21.2	−1 10.7	
Sept. 21...	9 55.6	+2.16	+12.1	10 07.7		
"	59.7	+1.58	+ 8.8	08.6		
"	10 05.7	+1.00	+ 5.5	11.2		
"	11.4	+0.22	+ 1.3	12.7		
			Mean	10 10.0	−1 08.2	
Sept. 28...	10 02.3	+9.05	+53.3	10 55.6		
"	06.4	+8.08	+47.1	53.5		
"	16.9	+6.09	+34.7	51.6		
"	22.4	+5.78	+33.0	55.4		
"	32.7	+3.44	+19 4	52.1		
"	38.1	+2.85	+16.0	54.1		
"	53.9	+0.22	+ 1.3	55.2		
			Mean	10 53.9	−1 06.5	
Oct. 1.....	8 22.7	+0.48	+ 2.7	8 25.4		
"	27.7	−0.43	− 2.4	25.3		
"	49.0	−4.40	−24.8	24.2		
			Mean	8 25.0	−1 05.9	
Oct 5.....	11 13.2	+4.56	+25.8	11 39.0		
"	17.2	+3.66	+20.7	37.9		
"	25.7	+2.42	+13.6	39.3		
"	31.5	+0.88	+ 4.9	36.4		
			Mean	11 38.1	−1 05.0	

Date.	*t*	*m*	∆*t*	*T*	*R*	Remarks.
1880	H M	"	M	H M	H M	
Oct. 13....	7 46.9	+4.69	+26.6	8 13.5		
"	51.7	+3.26	+18.4	10.1		
"	56.4	+2.91	+16.3	12.7		
"	8 00.8	+1.99	+11.1	11.9		
"	09.8	+0.10	+ 0.6	10.4		
"	14.5	−0.73	− 4.1	10.4		
			Mean	8 11.5	−1 03.3	
Oct. 23....	7 04.7	−6.63	−38.0	6 26 7		
"	08.3	−6.90	−39.7	28.6		
"	13.2	−7.88	−46.4	26.8		
"	16.9	−8.76	−51.4	25.5		
			Mean	6 26.9	−1 01.6	
Nov. 1....	8 23.6	+3.99	+22.5	8 46.1		
"	28.8	+2.99	+16.8	45.6		
"	42.1	+0.28	+ 1.5	43.6		
"	9 19.8	−5.89	−33.6	45.2		
"	23.7	−6.59	−37.8	45.9		
			Mean	8 45.3	−1 00.5	
Nov. 13 ..	8 19.1	+3.41	+19.2	8 38.3		
"	23.0	+2.52	+14.1	37.1		
"	27.0	+1.96	+10.9	37.9		
"	31.1	+1.28	+ 7.1	38.2		
			Mean	8 37.9	−1 00.0	
Nov. 16...	6 06.7	+0.25	+ 1.4	6 08.1		
"	11.0	−0.81	− 4.5	06.5		
"	16.5	−1.82	−10.1	06.4		
"	21.0	−2.35	−13.2	07.8		
			Mean	6 07.2	−1 00.1	
Nov. 26...	4 44.0	−3.72	−20.9	4 23.1		
"	47.7	−4.27	−24.1	23.6		
"	51.1	−4.93	−27.9	23.2		
"	55.0	−5.58	−31.8	23.2		
			Mean	4 23.3	−1 00.5	
Dec. 3....	4 56.9	+2.05	+11.5	5 08.4		
"	5 10.0	−0.25	− 1.4	08.6		
"	13.7	−1.06	− 5.8	07.9		
"	24.5	−2.97	−16.7	07.8		
"	28.3	−3.55	−20.0	08.3		
			Mean	5 08.2	−1 01.2	

Date.	*t*	*m*	△ *t*	*T*	*R*	Remarks.
1880	H M	″	M	H M	H M	
Dec. 8....	4 40.5	−4.10	−23.1	4 17.4		
“	43.6	−4.85	−27.5	16.1		
“	46.3	−4.94	−28.0	18.3		
“	48.7	−5.56	−31.7	17.0		
“	51.6	−5.81	−33.1	18.5		
“	55.3	−6.36	−36.4	18.9		
“	59.2	−7.32	−42.2	17.0		
			Mean	4 17.6	−1 01.9	
Dec. 10...	5 52.2	+0.42	+ 2.4	5 54.6		
“	55.0	−0.30	− 1.6	53.4		
“	58.2	−0.76	− 4.2	54.0		
“	6 01.3	−0.35	− 1.9	59.4		
			Mean	5 55.3	−1 02.1	
Dec. 12...	6 51.3	+7.86	+46.2	7 37.5		
“	55.2	+6.54	+37.5	32.7		
“	7 01.1	+5.91	+33.8	34.9		
“	07.2	+4.40	+24.8	32.0		
“	12.1	+3.92	+22.1	34.2		
“	16.4	+2.97	+16.7	33.1		
			Mean	7 34.1	−1 02.5	
Dec. 27...	5 07.2	−1.28	− 7.2	5 00.0	−1 06.0	Approximate, seeing too poor.
Dec. 31...	8 12.7	+0.29	+ 1.6	8 14.3		
“	16.0	+0.34	+ 1.9	17.9		
“	27.3	−1.72	− 9.6	17.7		
“	31.8	−2.36	−13.2	18.6		
			Mean	8 17.1	−1 06.8	
1881 Jan. 10...	7 05.7	−5.39	−30.7	6 35.0		
“	08.5	−5.77	−32.9	35.6		
			Mean	6 35.3	−1 10.0	
Jan. 17...	7 25.6	−1.06	− 5.8	7 19.8		
“	30.8	−1.80	−10.0	20.8		
“	34.3	−2.43	−13.6	20.7		
“	37.3	−2.93	−16.4	20.9		
			Mean	7 20.5	−1 12.2	
Jan. 27...	5 46.0	−0.60	− 3.4	5 42.6		
“	50.4	−1.50	− 8.4	42.0		
“	54.7	−2.02	−11.3	43.4		
“	57.2	−2.73	−15.3	41.9		
			Mean	5 42.5	−1 16.1	

Date.	t	m	Δt	T	R	Remarks.
1881	H M	″	M	H M	H M	
June 17 . .	16 49.8	+6.63	+38.0	17 27.9		
"	55.8	+5.45	+31.0	26.8		
			Mean	17 27.3	−2 09.8	
June 20 . .	15 26.0	−5.21	−29.6	14 56.4		
"	31.5	−5.43	−30.9	15 00 1		
			Mean	14 58.2	−2 10.4	
June 22 . .	16 42.2	−0.81	− 4.5	16 37.7		
"	46.1	−1.82	−10.4	35.7		
			Mean	16 36.7	−2 10.9	
July 28. .	15 46.5	+6.25	+35.7	16.22.2		
"	52.1	+4.70	+26.6	18.7		
"	59.9	+3.17	+17.8	17.7		
"	16 26.1	−1.22	− 6.8	19.3		
			Mean	16 19.5	−2 16.9	
Aug. 2. . . .	15 26.3	+0.15	+ 0.8	15 27.1		
"	30.7	−0 51	− 2.8	27.9		
"	38.7	−1.92	−10.7	28.0		
			Mean	15 27.7	−2 17.3	
Aug. 9. . . .	16 01.2	+2.35	+13.2	16 14.4		
"	06.6	+1.34	+ 7.5	14.1		
"	12.6	−0.04	− 0 2	12.4		
"	16.6	−0.78	− 4.4	12.2		
			Mean	16 13.3	−2 17.8	
Aug. 24. . .	13 38.5	+0.39	+ 2.2	13 40.7		
"	45.2	−0.78	− 4.3	40.9		
"	14 09.8	−5.80	−33.1	36.4		
			Mean	13 39.3	−2 18.0	
Sept. 5 . . .	13 34.1	−0.94	− 5.2	13 28.9	−2 17.7	Clouded, poor seeing.
Sept. 21 . .	16 31.6	+1.02	+ 5.7	16 37.3		
"	36.7	−0.26	− 1.4	35.3		
"	41.1	−0.93	− 5.2	35.9		
"	45.4	−1.38	− 7.7	37.7		
			Mean	16 36.5	−2 16.1	
Sept. 22 . .	12 17.3	+1.69	+ 9.4	12 26.7		
"	22.4	+0.73	+ 4.1	26.5		Clouded up.
			Mean	12 26.6	−2 16.0	

Date.	*t*	*m*	△*t*	*T*	*R*	Remarks.
1881	H M	"	M	H M	H M	
Oct. 7	9 00.5	+8.41	+49.2	9 49.7		
"	04.6	+7.36	+42.5	47.1		
"	08.2	+6.59	+37.8	46.0		
"	11.7	+6.07	+34.6	46.3		
			Mean	9 47.3	−2 13.6	
Oct. 9	11 18.3	+1.17	+ 6 5	11 24.8		
"	23.7	−0.02	− 0.1	23.6		
"	30.9	−0.86	− 4.8	26.1		
"	34.0	−1.61	− 9.0	25.0		
			Mean	11 25.0	−2 13.2	
Oct. 24 ...	9 02.3	−3.17	−17.8	8 44.5		
"	06.2	−4.15	−23.4	42.8		
"	10.5	−4.50	−25.4	45.1		
"	15.1	−5.85	−30.4	44.7		
			Mean	8 44.3	−2 10.1	
Oct. 26 ...	9 39.4	+7 22	+41.6	10 21.0		
"	44.0	+6.09	+34.7	18.7		
"	48.0	+5.72	+32.6	20.6		
"	51.9	+5.09	+28.9	20.8		
			Mean	10 20.3	−2 09.7	
Nov. 5....	8 19.0	+2.26	+12.6	8 31.6		
"	26.6	+1.46	+ 8.1	34.7		
"	31.0	+0.58	+ 3.2	34.2		
			Mean	8 33.5	−2 07.3	
Nov. 9....	11 20.6	+5.33	+30.3	11 50.9		
"	25.5	+4.35	+24.6	50.1		
"	38.0	+2.26	+12.6	50.6		
"	41.4	+1.95	+10.9	52.3		
			Mean	11 51.0	−2 06.4	
Nov. 19...	9 29.1	+5.95	+33.9	10 03.0		
"	34.6	+5.11	+29.0	03.6		
"	40.4	+3.97	+22.4	02.8		
"	45.7	+3.31	+18.6	04.3		
			Mean	10 03.4	−2 04.4	
Nov. 21...	11 43.0	−0.55	− 3.1	11 39.9		
"	46.5	−1.19	− 6.6	39.9		
			Mean	11 39.9	−2 04.0	

Date.	t	m	Δt	T	E	Remarks.
1881	H M	"	M	H M	H M	
Nov. 22...	7 02.6	+5.48	+31.2	7 33.8		
“	05.9	+4.56	+25.8	31.7		
“	09.4	+4.13	+23.3	32.7		
“	13.3	+3.54	+20.0	33.3		
			Mean	7 32.9	−2 03.8	
Nov. 24...	8 36.0	+5.63	+32.1	9 08.1		
“	39.2	+5.78	+33.0	12.2		
“	42.6	+4.93	+27.9	10.5		
“	46.3	+4.17	+23.5	09.8		
			Mean	9 09.1	−2 03.5	
Dec. 1....	9 36.0	+3.50	+19.7	9 55.7		
“	39.4	+3.00	+16.8	56.2		
“	43.2	+2.05	+11.5	54.7		
“	47.0	+1.62	+ 9.0	56.0		
			Mean	9 55.6	−2 02.5	
Dec. 4....	7 39.4	−2.76	−15.4	7 24.0		
“	42.4	−3.24	−18.2	24.2		Obs. stopped by clouds; one limb
			Mean	7 24.1	−2 02.0	
Dec. 6....	8 55.5	+1.17	+ 6.5	9 02.0		
“	9 00.1	+0.48	+ 2.6	02.7		
			Mean	9 02.3	−2 01.7	
Dec. 14...	5 57.7	−3.44	−19.3	5 38.4		
“	6 00.9	−3.62	−20.4	40.6		
“	05.8	−5·02	−28.5	37.3		
“	10.1	−5.74	−32.7	37.4		
			Mean	5 38.4	−2 01.2	
Dec. 18...	8 37.2	+3.41	+19.2	8 56.4		
“	41.8	+2.19	+12.3	54.1		
“	47.2	+1.00	+ 5.6	52.8		
			Mean	8 54.4	−2 01.0	
Dec. 23...	8 04.9	−0.62	− 3.5	8 01.4		
“	08.7	−1 57	− 8.7	00.0		
			Mean	8 00.7	−2 01.0	
Dec. 28...	6 56.4	+2.48	+13.9	7 10.3		
“	7 00.1	+1.20	+ 6.7	06.8		
“	17.8	−1.91	−10.6	07 1		
“	21.8	−2.26	−12.6	09.2		
			Mean	7 08.3	−2 01.2	

Date.	t	m	△t	T	R	Remarks.
1882	H M	"	M	H M	H M	
Jan. 9....	6 57.6	+0.00	+ 0.0	6 57.6		
"	7 01.0	−0.30	− 1.7	59.3		
"	04.9	−0.80	− 4.5	60.4		
"	11.0	−2.22	−12.4	58.6		
			Mean	6 59.0	−2 02.3	
Jan. 11...	8 01.5	+6.25	+35.7	8 37.2		
"	07 3	+5.51	+31.4	38.7		
"	12.5	+4.27	+24.1	36.6		
"	17.0	+3.99	+22.5	39.5		
			Mean	8 38.0	−2 02.6	
Jan. 14...	5 57.1	+1.80	+10 0	6 07.1		
"	6 00.7	+1.84	+10.2	10.9		
"	06.4	+0.31	+ 1.7	08.1		
			Mean	6 08.7	−2 03.0	
Feb. 2....	6 31.7	+3.26	+18.3	6 50.0		
"	34.9	+2.39	+13.4	48.3		
"	38.3	+1.91	+10.8	49.1		
"	41.5	+1.28	+ 7.1	48.6		
			Mean	6 49.0	−2 07.2	
Feb. 4....	7 59.6	+5.70	+32.5	8 32.1		
"	8 03.2	+4.96	+28.1	31.3		
"	09.5	+4.14	+23.4	32.9		
"	12.8	+3.17	+17.8	30.6		
			Mean	8 31.7	−2 07.7	
Feb. 7 ..	6 02.4	+0.18	+ 1.0	6 03.4		Cloudy.
"	07.7	−1.16	− 6 4	01.3		
			Mean	6 02.4	−2 08.6	
Feb. 9....	7 28.5	+2.28	+12.7	7 41.2		
"	31.4	+1 67	+ 9.3	40.7		
"	39.0	+0.28	+ 1.4	40.4		
"	42.2	−0.35	− 2.0	40.2		
			Mean	7 40.6	−2 09 2	
Feb. 14...	6 38.0	+2.78	+15.6	6 53.6		Very poor seeing, high wind.
"	41.5	+1.43	+ 8.0	49.5		
"	47.5	+0.13	+ 0.8	48.3		
"	51.1	+0.12	+ 0.8	51.9		
			Mean	6 50.8	−2 10.6	
Feb. 23...	8 29.1	+8.22	+47.9	9 17.0	−2 13.6	

Date.	t	m	Δt	T	R	Remarks.
1882	H M	″	M	H M	H M	
March 22.	6 39.0	+ 0.98	+ 5.5	6 44.5		
"	42.3	+ 0.19	+ 1.1	43.4		
"	7 09.8	− 4.64	−26.3	43.5		
			Mean	6 43.8	−2 24.0	
March 29.	7 11.3	+ 3.31	+18.6	7 29.9		
"	18 3	+ 2.05	+11.4	29.7		
			Mean	7 29.8	−2 26.8	

EQUATORIAL WHITE SPOTS ON ♃.

Date.	t	m	Δt	T	R	Remarks.
1879	H M	″	M	H M	H M	
Sept. 10...	11 16.0	+13.19	+71.2	12 27.2	− 2.4	Foll. limb, Lat. obs., −2″.40
Sept. 20...	9 33.5	−13.46	−73.0	8 20.5	− 0.8	Prec. limb, Lat. obs., −2″.03
1880.						
July 8....	14 19.3	− 9.23	−47.2	13 32.1	−1 16.8	Lat. obs., −1″.92
July 17...	14 52.0	−11.18	−58.5	13 53.5	−1 16.8	
July 24...	13 10.6	− 1.29	− 6.3	13 04.3		Lat. obs., −2″.53
"	17.4	− 2.66	−13.1	04.3		Second spot following.
"	25.9	− 4.36	−21.6	04.3		Diff. long. obs., 25.0 min.
			Mean	13 04.3	−1 16.9	
Aug. 4....	14 22.9	+ 1.86	+ 9.1	14 32.0		
"	35.8	− 0.34	− 1.7	34.1		
"	40.2	− 1.19	− 5.9	34.3		
			Mean	14 33.5	−1.16.3	
Aug. 6....	15 19.8	+ 4.11	+20.3	15 40.1		
"	31.2	+ 2.18	+ 9.1	40.3		
"	35.2	+ 1.07	+ 5.2	40.4		
			Mean	15 40.3	−1 16.0	
Aug. 11...	13 17.1	+ 5.20	+25.8	13 42.9		
"	24.1	+ 3.77	+18.6	42.7		
"	30.8	+ 2.56	+12.6	43.4		
"	35.8	+ 0.84	+ 4.1	39.9		
			Mean	13 42.2	−1 15.6	

Date.	*t*	*m*	Δ*t*	*T*	*R*	Remarks.
1880	H M	″	M	H M	H M	
Sept. 3....	12 03.6	+3.37	+16.6	12 20.2		
"	07.2	+2.22	+11.0	18.2		
"	13.7	+0.90	+ 4.5	18.2		
"	17.2	+0.36	+ 1.8	19.0		
			Mean	12 18 9	−1 12.0	
Sept. 10.	10 52.9	+6.68	+33.4	11 26.3		
"	57.4	+6.31	+31.5	28.9		
"	11 06.7	+4.16	+20.6	27.3		
"	11.8	+2.88	+14.1	25.9		
			Mean	11 27.1	−1 10.6	
Sept. 24...	9 58.3	−3.07	−15.1	9 43.2		Lat. observed, −2″.96, from S. Pole only
"	10 02.5	−3.81	−18.8	43.7		
"	08.4	−5.20	−25.8	42.6		
"	18.5	−7.16	−35.9	42.6		
			Mean	9 43.0	−1 07 4	
Oct. 1.....	8 24.9	+5.49	+27.2	8 52.1*		* Difference of Long. from the Red Spot
"	54.8	+0.13	+ 0.6	55.4		
"	58.2	−1.06	− 5.2	53.0		
			Mean	8 53.5	−1 05.9	
Oct. 28....	10 26.2	−1.94	− 9.5	10 16.7		Lat obs., −2″.80
"	34.1	−2.75	−13.5	20.6		
"	38.6	−3.52	−17.5	21.1		
			Mean	10 19.5	−1 01.0	
Nov. 2....	7 35.9	+8.67	+44.1	8 20.0		White Spot prec.—59.2 min.
"	43.4	+7.47	+37.5	20.9		
"	53.4	+5.60	+27.9	21.3		White Spot prec. and north−18.1 min.
			Mean	8 20.7	−1 00.4	
Nov. 8....	11 31.1	+4.98	+24.5	11 55.6		White Spot prec.—18.5 min.
"	35.5	+3.36	+16.5	52.0		White spot foll.—22.6 min.
			Mean	11 53.8	−1 00.1	
Dec. 2....	5 50.1	+6.60	+33.0	6.23.1		Lat. observed—−2″.95, from South pole only.
"	5 54.0	+5.41	+26.9	20.9		
"	6 03.5	+3.49	+17.2	20.7		
"	10.3	+2.34	+11 5	21.8		
"	20.0	+0.21	+ 1.0	21.0		
			Mean	6 21.5	−1 01.1	

Date.	*t*	*m*	Δ *t*	*T*	*R*	Remarks.
1880	H M	″	M	H M	H M	
Dec. 6....	8 25.2	+ 5.17	+25.6	8 50.8		
"	29.3	+ 4.50	+22.2	51.5		
"	32.8	+ 3.92	+19.3	52.1		
"	36.3	+ 3.10	+15.2	51.5		
"	42.6	+ 1.97	+ 9.5	52.1		
			Mean	8 51.6	−1 01.6	
Dec. 9....	5 07.2	+ 7.04	+35.3	5 42.5		Approximate diameter of white spot, 1″.37 M. D. 1″.19
"	11.4	+ 6.02	+30.0	41.4		
"	16.2	+ 5.46	+27.1	43.3		
"	22.1	+ 4.25	+21.0	43.1		
"	26.2	+ 3.13	+15.5	41.7		
			Mean	5 42.4	−1 02.0	
Dec. 31...	8 19.5	+ 6.39	+31.9	8 51.4		
"	22.7	+ 5.64	+28.0	50.7		
			Mean	8 51.1	−1 06.9	
Jan. 30...	6 44.6	+ 3.68	+18.1	7 02.7		Spot not conspicuous, seeing good.
"	48.0	+ 2.58	+12.6	00.6		
"	52.3	+ 1.93	+ 9.5	01.8		
			Mean	7 01.7	−1 17.2	
July 22...	16 14.0	+ 2.00	+10.0	16 24.0	−2 16.2	White spot prec. Δ *m*., 5″.56 Δ *t*., 27.5 min.
Aug. 9....	16 33.0	+ 2.59	+12.7	16 45.7	−2 17.8	Prec. end of rift.
Sept. 1....	14 46.7	+10.55	+54.6	15 41.3	−2 17.9	Very poor seeing, single measure.
Sept. 21...	16 59.2	+ 6.80	+34.0	17 33.2		Prec. end of rift.
"	17 03.5	+ 5.86	+29.2	32.7		Lat. obs., 3″.77
			Mean	17 33.0	−2 16.1	
Oct. 8	12 02.5	+11.48	+60.2	13 02.7		Foll. spot.
"	07.8	+10.10	+52.2	00.0		Lat. obs., 2″.85
"	12.4	+ 9.37	+48.0	00.4		Prec. spot not measured.
"	19.4	+ 8.13	+41.1	00.5		
			Mean	13 00.9	−2 13.4	
Oct. 18 ...	9 36.8	− 7.87	−39.8	8 57.0		
"	40.4	− 8.19	−41.5	58.9		
			Mean	8 58.0	−2 11.4	

Date.	t	m	Δt	T	R	Remarks.
1881	H M	″	M	H M	H M	
Oct. 20 . . .	9 45.0	+ 4.68	+23.1	10 08.1		
"	49.1	+ 3.72	+18.3	07.4		
"	56.9	+ 1.79	+ 8.8	05.7		
"	10 03.6	+ 0.89	+ 4.3	07.9		
			Mean	10 07.3	−2 11.0	
Nov. 5. . . .	8 36.4	+11.15	+58.2	9 34.6	−2 07.3	Clouded up
Nov. 9. . . .	11 30.3	+ 4.68	+23.1	11 53.4		
"	33.3	+ 4.29	+21.2	54.5		
"	45.9	+ 1.69	+ 8.3	54.2		
"	49.3	+ 1.02	+ 5.0	54.3		
			Mean	11 54.1	−2 06.4	
Nov. 14. . .	9 22.7	+ 5.98	+29.8	9 52.5		Single reading
"	27.9	+ 6.40	+32.0	59.9		
			Mean	9 56.2	−2 05.3	
Nov. 21. . .	9 05.5	+ 1.63	+ 8.0	9 13.5		End of rift not sharply defined
"	09.4	+ 0.75	+ 3.6	13.0		
"	12.7	+ 0.01	+ 0.0	12.7		
"	15.7	− 0.32	− 1.6	14.1		
			Mean	9 13.3	−2 04.0	
Nov. 24. . .	6 43.3	− 7.33	−36.9	6 06.4		End of long rift
"	47.2	− 7.93	−40.0	07.2		
			Mean	6 06.8	−2 03.5	
Nov. 26. . .	7 09.2	+ 1.90	+ 9.4	7 18.6		White spot foll.
"	12.5	+ 0 92	+ 4.5	17.0		Δt=27.5 min.
"	15.4	+ 0.19	+ 1.0	16.4		Lat. obs. foll. spot, −2″.57
"	18.3	− 0.08	− 0.4	17.9		Lat. obs. prec. spot, −3″.10
			Mean	7 17.5	−2 03.1	
Dec. 7. . . .	8 22.0	+ 4.32	+21.3	8 43.3		Lat. obs., −2″.97
"	25.1	+ 3.55	+17.5	42.6		
"	29.5	+ 2.66	+13.1	42.6		
"	32.8	+ 2.38	+11.7	44.5		
			Mean	8 43.2	−2 01.7	
Dec. 9. . . .	9 46.6	+ 1.05	+ 5.1	9 51.7		
"	49.5	+ 0.60	+ 3.0	52.5		
			Mean	9 52.1	−2 01.4	

Date.	*t*	*m*	Δ*t*	*T*	*R*	Remarks.
1881	H M	″	M	H M	H M	
Dec. 10...	5 32.8	− 0.21	− 1.0	5 31.8		Lat. obs.−3″.41.
"	35.1	− 0.59	− 2.8	32.3		White Spot foll.
"	37.9	− 0.96	− 4.7	33.2		Δ*t*.= +23.0 min.
"	40.2	− 1.47	− 7.3	32.9		Not well defined.
			Mean	5 32.5	−2 01.4	
Dec. 14...	7 46.3	+ 1.20	+ 5.9	7 52.2		
"	48.9	+ 0.83	+ 4.0	52.9		
"	52.0	+ 0.34	+ 1.6	53.6		
"	55.1	− 0.25	− 1 3	53.8		
			Mean	7 53.1	−2 01.1	
Dec. 23...	8 11.8	+ 0.53	+ 2.6	8 14.4		
"	15.6	− 0.74	− 3.6	12.0		
			Mean	8 13.2	−2 01.0	
Dec. 28...	6 39.0	− 4.85	−24.0	6 15.0		
"	42.5	− 5.50	−27.4	15.1		
			Mean	6 15.0	−2 01.2	
1882.						
Jan. 17....	7 55.9	+ 4.73	+23.4	8 19.3		
"	59.7	+ 3.98	+19.6	19.3		
"	8 02.3	+ 3.51	+17.3	19.6		
"	04.8	+ 2.85	+14.0	18.8		
			Mean	8 19.3	−2 03 6	
Jan. 22....	6 29.2	− 2.39	−11.7	6 17.5		
"	32.7	− 2.86	−14.0	18.7		
"	43.3	− 4.81	−23.8	19.5		
			Mean	6 18.6	−2 04.6	
Jan. 24...	7 38.6	− 1.98	− 9.7	7 28.9		White Spot prec.
"	41.3	− 2.50	−12.3	29.0		20.1 min.
			Mean	7 29.0	−2 05.0	White Spot foll.; the foll. end of rift, 25.7 min.
Jan. 29...	5 32.7	− 3.29	−16.2	5 16 5		White Spot foll.
"	35.4	− 3.75	−18.5	16.9		Δ*t*= +23.0 min.
			Mean	5 16.7	−2 05.9	Not well outlined. Foll. Spot is the standard one.
Feb. 2....	7 04.1	+10.68	+55.4	7 59.5		
"	08.8	+ 9.75	+50 0	58.8		
"	12.8	+ 8.95	+45.6	58.4		
			Mean	7 58.9	−2 07.2	

Date.	t	m	Δt	T	R	Remarks.
1882	H M	''	M	H M	H M	
			+34.4			
Feb. 4....	8 21.3	+ 6.69	+10.4	9 06.1	—2 07.6	Diff. Long. from Red Spot. Spot is the end of a rift.
Feb. 7....	6 11.7	− 2.27	−11.1	6 00.6		
"	14 4	− 2.77	−13.6	00.8		
			Mean	6 00.7	—2 08.6	
Feb. 9....	6 49.7	+ 4.02	+19.9	7 09.6		Foll. White Spot nearer the Equator. Δt=23.5 min.
"	7 03.1	+ 1.96	+ 9.6	12.7		
"	06.8	+ 0 60	+ 3.0	09.8		
			Mean	7 10.7	—2 09.1	
Feb. 16...	6 36.0	+ 0.49	+ 2.4	6 38.4		
"	40.9	− 1.23	− 6.0	34.9		
"	44.8	− 1.47	− 7.2	37.3		
			Mean	6 36.9	—2 11.3	
March 1..	8 18.4	+11.20	+58.6	9 17.0		Poor seeing, very difficult.
"	25.8	+ 9.66	+49.6	15.4		
			Mean	9 16.2	—2 15.8	
March 22.	6 43.8	+ 2.68	+13.2	6 57.0	—2 24.0	Diff. Long. from R Spot.
March 31.	7 05.1	+ 4.59	+22.7	7 27.8	—2 27.7	

SMALL BLACK SPOT ON BELT NO. 2.

Date.	*t*	*m*	Δ*t*	*T*	Long. from Red Spot	Remarks.
1880	H M	″	M	H M	H M	
Aug. 5....				16 35	+ 0.0	Nearly long. of red spot estimated.
Sept. 4....				11 15	+ 0.0	Estimated.
Sept. 9....		−0.52		10 18.3	− 2.9	Referred to red spot.
Oct. 1.....		−1.58		8 15.7	− 9.3	Referred to red spot.

SMALL BLACK SPOT ON BELT NO. 2.

Sept. 4....	13 29.1		+ 8.0	13 37.1	+2 21.8	
Sept. 9....	12 12.8	+4.92	+29.2	12 42.0	+2 20.8	
Oct 6.....	10 28.2	−5.07	−30.3	9 57.9	+2 28.7	Difficult. Lat. obs. +9″.66.

BLACK SPOT ON BELT NO. 3.

Nov. 26...	5 31.1	+5.46	+28.6	6 01.7		Lat. obs., +5″.99. Well defined and black.
"	38.2	+4.38	+22.8	01.0		
"	41.5	+3.82	+19.8	01.3		
"	44.7	+3.33	+17.2	01.9		
			Mean	6 01.5	+1 38.2	
Dec. 3....		+1.16	+ 6.4	5 14.6	+ 6.4	

On December 3, the spot observed, was preceded and followed by ill-defined patches on this belt. If the objects observed on November 26 and December 3 are identical, the motion is the same as for the equatorial white spots, viz: a period of $9^h\ 50^m\ 08^s.5$.

OVAL WHITE SPOT ON BELT NO. 2.

Aug. 4...	13 45.4	−0.40	− 2.4	13 43.0	+2 54.7	Lat. obs., +10″.46.
Aug. 6...	15 09.7	+2.69	+15.9	15 25.6	+2 59.4	Very faint.
Aug. 26...	12 21.3	−4.99	−29.7	11 51.6	+3 00.7	Cloudy.
Sept. 4....	14 01.1		+14.2	14 15.3	+3 00.0	Not very distinct.
Oct. 6	10 40.3	−0.13	− 1.0	10 39.3	+3 10.0	Very hard to see.

BLACK SPOT ON BELT NO. 2.

Aug. 4....	15 00.9	+1.47	+ 8.8	15 09.7		Assumed lat., +10″.0.
"	07.0	+0.46	+ 2.7	09.7		
			Mean	15 09.7	+4 21.4	Spot entirely black; about 1″ in width and 2″ in length.
Aug. 6....	16 18.0	+4.83	+28.8	16 46.8		
"	27.7	+3.67	+21.7	49.4		
			Mean	16 48.1	+4 21.9	

OVAL WHITE SPOTS ON BELT No. 6.

Date.	*t*	*m*	Δ *t*	*T*	Long. from Red Spot	Remarks.
1880	H M	″	M	H M	H M	
Aug. 4 …	14 26.2	+3.34	+21.4	14 47.6	+3 59.3	Lat. obs—11″.62.
"	14 30.9	+6.38	+41.9	15 12.8	+4 24 5	Foll. spot. Spots about 0″.5 in diam.
Aug. 6….	16 06 3	+2.64	+16.9	16 23.2	+3 57.3	
"	diff.lon.	+4.38	+29.3	16 52.5	+4 26 6	Foll. spot.
Oct. 6 ….	11 08.6	+1.65	+10.5	11 19.1		Another white spot, north and between (1) and (2).
"	16.9	−0.08	− 0.5	16.4		
"	35.3	−2.52	−16.0	19.3		
			Mean	11 18.3	+3 48.9	
	diff.lon.	+5.12	+33.1	11 51.4	+4 22.0	Foll. spot.

OVAL WHITE SPOTS ON BELT No. 6.

These spots were about one-second of arc in length, and at all times were very difficult to see. They were only visible when the seeing was good.

Date.	*T*	Name.	Long. from Red Spot.	Remarks.
1881	H M		H M	
Oct. 10 …….	10 03.4	*a*	+2 47.4	Lat. obs.—12″.60.
"	10 13.0	*b*	+2 57.0	Lat. obs.—9″.59.
"	10 36.5	*c*	+3 20.5	Lat. (est)—9″.6.
Dec. 24…….	7 38.7	*a*	+3 44.7	
"	7 51.9	*b*	+3 59.0	
"	8 11.0	*c*	+4 18.0	
1882				
Jan. 17 ……		*a*	+3 29.8	
"	7 13.5	*b*	+3 35.8	Lat. obs.—10″.00.
"		*c*	+3 52.0	
1881				
Sept. 9 …….	11 58.2	*f*	+5 09.1	Lat. obs.—10″.78.
Oct. 10 …….	11 16.6	*d*	+4 00.6	Lat. obs.—10″.00.
"	11 57.6	*e*	+4 41.6	Lat. (est)—9″ 6.
Oct. 20 …….	9 24.3	*d*	+3 55.7	
"	10 11.5	*e*	+4 42.9	
Oct. 25 …….	9 08.2	*e*	+4 32.8	Lat. obs.—10″.29.
"	9 52.9	*f*	+5 17.5	Lat. obs.—11″.49.
"	10 08.6	*g*	+5 33.2	Lat. obs.—10″.29.
"	10 28 0	*h*	+5 52.6	Lat. (est)—11″.5.
Nov. 21 ……	6 52.0	*f*	+5 07.7	
Dec. 7………	7 25.1		+2 32.1	Lat. obs.—9″.83.
Dec. 10…….	7 17 est		+4 55.0	Lat. obs.—11″.51.
"	7 18.5		+4 56.4	Lat. obs.—10″.24.
"	8 07 est		+5 45.0	Lat. (est)—11″.5.
1882				
Jan. 17 …….			+2 23.5	
"	6 26.9		+2 48.0	

SMALL WHITE SPOT ON SOUTH MARGIN OF EQUATORIAL BELT.

Date.	t	m	Δ t	T	*Long. fr. Eq.w. spot*	Remarks.
1881	H M	″	M	H M	H M	
Oct. 25....	10 21.4	− 0.10	− 0.5	10 20.9	+2 11.9	
Nov. 24...	8 21.9	− 0.89	− 4.3	8 17.6	+2 08.9	
Dec. 10...	7 33.3	− 0.87	− 4.3	7 29.0	+1 56.5	
1882						
Jan. 11...	6 49.0	− 7.79	−39.3	6 09.7	+1 26.0	Probably the second spot obs. March 2.
March 2..	7 39.3	− 8.63	−43.8	6 55.5	+1 59.0	Two small spots.
March 2..		− 4.19	−24.9	6 30.6	+1 34.1	

The spot observed from October 25 to January 11 is presumed to be the same object. It was very minute and could only be fairly seen with a power of at least 400. The rotation period is about seventeen seconds shorter than for the Equatorial white spot, but the motion is not uniform, as may be inferred from the numbers in the sixth column.

CLOUDY PATCH IN THE EQUATORIAL BELT.

Date.	T	*Long. from Eq. white spot*	Date.	T	*Long. from Eq. white spot*
1881	H M	H M	1881	H M	H M
Oct. 18......	8 18.3	+0 56.0	Nov. 26.....	9 54.1	+0 60.8
Oct. 20......	9 06.1	+0 50.5	Dec. 14.....	10 57.8	+1 13.0
Nov. 24.....	7 51.6	+0 44.9	Dec. 28.....	6 51.7	+1 36.5

An ill-defined cloudy patch on the Equatorial belt, following the Equatorial white spot and in the same latitude, was measured to ascertain whether the dark masses near the equator drifted with the same velocity as the white spot.

As the outline of this cloudy matter was not well defined, the micrometer measures are of necessity approximate.

An inspection of the above observations shows, however, that the drift of the dark matter in the Equatorial regions is essentially the same as for the white spots.

Two Oval White Spots on Belt No. 5.

Date.	*T*	*Long. from Red Spot*	*Dif. of long. of the two spots*	Remarks.
1881		H M	M	
Nov. 21...	foll. spot			Not measured.
Nov. 22...	7 58.4	+0 25.5		Lat. obs. −9″.63.
Nov. 24...	9 36.2	+0 26.1		
Dec. 1....	10 20.0	+0 24.4	60.0	
Dec. 6....	9 25.6	+0 23.3		
Dec. 23...	8 13.2	+0 12.5		
Dec. 28 ..	7 14.9	+0 06.6	42.0	
1882				
Jan. 9....	6 53.6	−0 05.4	46.3	Lat. obs. −10″.00.
Feb. 4....	8 02.3	−0 29.4	43.0	
Feb. 23...	8 34.2	−0 42.8	33.5	

Oval White Spot on Belt No. 3.

Date.	*T*	*Long. from Red Spot*	*Long. from Eq. White Spot*	Remarks.
1881		H M		
Nov. 1....	9 25.8	+4 07.5	+2 04.	Lat. obs. +4″.59.
Dec. 14...	9 34.0	+3 55.6	+1 41.1	

RED SPOT ON ♃.

Length, Breadth and Latitude.

The following tables give the individual observations for the Length, Breadth and Latitude of the great Red Spot during the three oppositions of 1879, 1880 and 1881. h_0=distance in degrees from the central meridian at the time of observation. l=apparent length observed. L=Length of chord when on center of disc. B=Breadth. β=Latitude. All the quantities are reduced to the mean distance.

Date.	h_0	l	L	B	β	Remarks.
1879	°	″	″	″		
Sept. 11...	+ 18.1	10.57	11.12	3.26		
Sept. 18...					− 7.12	
Sept. 25...	+ 21.5	10.06	10.82		− 6.44	
	+ 12.8					Differential measure of length by Prof. Colbert.
Oct. 5 ...	− 10.6		13.27	2.38	− 7.56	
Oct. 10 ...	+ 22.6	10.90	11.80	3.05	− 7.11	
Oct. 14 ...	+ 29.3	11.36	13.03	3.61		
Oct. 15 ...	+ 2.4	13.20	13.21		− 7.00	
Oct. 20 ...	+ 53.2	7.33	12.24		− 7.14	
Oct. 22 ...				3.52		
Oct. 29 ...	+ 17.0	11.45	11.90	3.57	− 7.25	
1880 Feb. 10...	− 1.2	12.78	12.78		− 6.00	
		Mean	12.25	3.46	− 6.95	
June 9 ..	+ 15.4	10.29	10.67			
June 16 ..	+ 9.4	12.35	12.53	3.73	− 6.79	
July 3...	− 10.0	11.03	11.30		− 7.01	
July 5...	− 10.4	11.10	11.28	3.72	− 6.95	
July 8...	+ 13.1	11.35	11.66	3.28		
July 20...	+ 1.4	12.10	12.10			
July 22...	+ 10.3	11.20	11.38		− 7.09	
July 27...	− 8.0	11.82	11.94	3.32		
July 29...					− 7.50	
Aug. 3 ..	+ 0.1	11.37	11.37			
Aug. 5 ..	− 1.5	11.98	11.98	3.41		
Aug. 6 ..					− 7.42	
Aug. 11 ..					− 7.46	
Sept. 4...	+ 6.0	10.83	10.90	3.41	− 7.32	
Sept. 6...	+ 7.9	11.84	11.95			
Sept. 9...	+ 7.5	11.95	12.03	3.87	− 6.81	
Sept. 21...	+ 4.7	11.43	11.47			
Oct. 13 ...	− 18.5	10.95	11.55	3.39	− 7.04	
Nov. 26...	+ 11.7	10.50	10.73	3.63	− 7.09	
Dec. 10...	+ 6.9	10.86	10.94			
Dec. 12...	− 29.3	10.28	11.79			
Dec. 12...	− 8.8	11.09	11.23			
1881 Jan. 17 ...	+ 11.8	11.97	12.28	3.65	− 7.23	
		Mean	11.55	3.54	− 7.14	

Date.	h_0	l	L	B	β	Remarks.
1881	°	"	"	"		
June 20...					− 7.44	
June 22...		11.09	11.93			
July 28...	7.0	11.50	11.51		− 7.28	
Aug. 2...	10.0	11.46	11.64			
Aug. 4...					− 7.23	
Aug. 24...	8.8	11.22	11.36	3.54		
Sept. 21...	5.0	11.03	11.05			
Oct. 7 ...					− 7.50	
Oct. 24 ...					− 8.15	
Oct. 26 ...	14.6	10.97	11.34	3.41	− 6.95	
Nov. 21...	5.0	11.46	11.50	3.52		
Nov. 22...	7.0	11.49	11.57		− 7.33	
Dec. 28...	4.0	10.54	10.56			
1882						
Jan. 9	10.0	10.50	10.65		− 7.27	
Feb. 4...	9.6	10.89	11.04	4.17	− 7.26	
Feb. 14...	4.0	11.43	11.45			
March 22.	6.0	11.19	11.25		− 7.57	
		Mean	11.30	3.66	− 7.40	

♃'S EQUATORIAL BELT.

The following table gives the angle of position, latitude and width of the Equatorial belt.

P=Angle of position of the North edge. β=Latitude of the North edge. *W*=Width.

The angle of position has been compared with the position of ♃'s Equator, as given in Marth's Ephemerides, published in the "Monthly Notices," Royal Astronomical Society.

Date.	*P*	β *N E*	*W*	♃ *Equator Marth Eph*	*Obs–Eph*
1879	°	"	"	°	°
Aug. 27...	64.4			65.8	−1.4
" 29...	65.5			65.8	−0.3
" 30...	65.3			65.9	−0.6
Sept. 3...	65.5	+2.53	6.09	65.9	−0.4
" 9...	66.7			65.9	+0.8
" 10...	65.7	+2.81	6.59	66.0	−0.3
" 16...	66.0			66.2	−0.2
" 18...		+2.20	6.90		
" 20...	66.6	+2.84	6.04	66.3	+0.3
" 24...	66.2	+3.22		66.3	−0.1
Oct. 2...	67.9			66.4	+1.5
" 6...	67.6	+2.57		66.4	+1.2
" 9...	67.1	+1.90	7.40	66.5	+0.6
" 10...	66.5			66.5	+0.0
" 14...	65.5	+2.81	6.25	66.6	−1.1
" 22...	65.6			66.6	−1.0
" 24...	66.7	+2.71	6.96	66.6	+0.1
" 29...	68.3			66.6	+1.7
Dec. 13...		+2.34	7.64		
1880					
Jan. 14...	64.2		7.10	65.2	−1.0
	Mean	+2.59	6.77		−0.01
June 16...	65.2	+2.57		65.6	−0.4
July 3...	65.9	+2.38	7.12	65.9	+0.0
" 5...	66.5	+2.59	7.77	66.0	+0.5
" 8...		+2.61	6.80		
" 20...	66.8		6.81	66.2	+0.6
" 22...	66.7	+2.04		66.2	+0.5
" 27...	66.2	+2.43	7.10	66.2	+0.0
Aug. 4...	67.0			66.3	+0.7
" 6...	67.1	+1.97	6.65	66.3	+0.8
" 11...	66.3			66.3	+0.0
" 12...	66.0			66.3	−0.3
" 26...	66.5			66.1	+0.4
Sept. 3...	65.0			66.1	−1.1
" 4...	66.6	+2.06	6.53	66.1	+0.5
" 9...		+2.27	6.45		
" 10...	66.8		7.11	66.0	+0.8
" 21...	65.5			65.8	−0.3
" 28...	66.0			65.7	+0.3

♃'s EQUATORIAL BELT.

Date.	*P*	*β N. E.*	*W*	*♃ Equator Marth Eph*	*Obs−Eph*	Remarks.
1879	°	″	M	/	°	
Oct. 13...	65.6	+ 2.44	6.93	65.5	+0.1	
" 23...	65.6		7.29	65.3	+0.3	
Nov. 2...	65.0			65.2	−0.2	
" 24...	64.5		7.68	65.0	−0.5	
" 26...	65.1	+ 2.23		65.0	+0.1	
Dec. 14...	66.2		7.22	65.2	+1.0	
1881						
Jan. 17...	65.2			65.4	−0.2	
" 19...	64.0		7.06	65.4	−1.4	
	Mean	+ 2.33	7.04		+0.09	
1881						
July 19...	75.1		5.99	74.3	+ 0.8	
July 28...	76.7			74.8	+ 1.9	
Aug. 2 ..			6.71			
Aug. 24 ..	77.9			75.9	+ 2.0	
Aug. 29 ..	76.0	+ 2.03	7.13	76.0	+ 0.0	
Oct. 5 ...	76.8		7.25	75.9	+ 0.9	
Oct. 7 ...	77.0			75.8	+ 1.2	
Oct. 8 ...	77.3	+ 2.01	6.87	75.8	+ 1.5	
Oct. 18 ...	76.6	+ 1.95		75.5	+ 1.1	
Oct. 26 ...	75.6	+ 2.37	6.94	75.1	+ 0.5	
Nov. 9...	74.3			74.5	− 0.2	
Nov. 14...	76.2			74.2	+ 2.0	
Nov. 26...	74.7			73.7	+ 1.0	
Dec. 1...	73.9			73.5	+ 0.4	
Dec. 7...	74.4			73.3	+ 1.1	
Dec. 10...	74.0		6.61	73.2	+ 0.8	
Dec. 17...	73 4	+ 2.14	7.30	73.0	+ 0.4	
1882						
Feb. 1....		+ 2.05	7.02			
Feb. 3....	74.2			72.9	+ 1.3	
Feb. 4....	72.7			72.9	− 0.2	
Feb. 8....	73.3			73.1	+ 0.2	
March 22..	74.8	+ 2.55	7.25	75.1	− 0.3	
March 31..	74.7			75.5	− 0 8	
	Mean	+ 2.16	6.91		+ 0.74	

ROTATION OF ♃ FROM THE GREAT RED SPOT.

The following table shows the error in longitude for every observation of the great red spot, as compared with an Ephemeris, extending from September 25, 1879 to March 29, 1882.

The first column is the date; second column, the number of days after the Epoch; third column, the time of transit reduced to the Zero Epoch; fourth column, the Ephemeris, corresponding to a uniform rotation period of $9^h\ 55^m\ 34^s.0$. Fifth column, Observation minus Ephemeris expressed in time, in which $5^m.6$ is equal to $1''$ of arc at mean distance.

Sixth column, the Ephemeris corresponding to the rotation period, $9^h\ 55^m\ 34^s.0 + t \times 0^s.00209$; seventh column, (Obs—Eph).

An examination of the residuals in column seven, shows that the formulas represent the individual observations very well, with the exception of about a month near the middle of the series.

The period, $9^h\ 55^m\ 34^s\ 0$ is probably too great for the date, September 25, 1879; but the observations made in 1878 are not sufficiently numerous to ascertain it with great precision.

		Rotation=9 55 34.0 (H M S)			9 55 34.0 + $t \times 0^s.00209$ (H M S)	
Date.	Days.	T_0	*Ephemeris*	*Obs—Eph*	*Ephemeris*	*Obs—Eph*
1879		H M	H M	M	H M	M
Sept. 25	0	11 27.6	11 28.9	− 1.3	11 28.9	−1.3
Oct. 5	10	9 40.7	9 42.5	− 1.8	9 42.5	−1.8
" 10	15	8 49.8	8 49.3	+ 0.5	8 49.3	+0.5
" 14	19	12 03.9	12 04.9	− 1.0	12 04.9	−1.0
" 15	20	7 59.6	7 56.1	+ 3.5	7 56.1	+3.5
" 29	34	9 26.7	9 25.4	+ 1.3	9 25.5	+1.2
1880						
Feb. 10	138	4 54.3	4 52.6	+ 1.7	4 54.3	0.0
May 6	224	15 26.5	15 26.1	+ 0.4	15 30.3	−3.8
June 9	258	13 29.3	13 22.5	+ 6.8	13 28.0	+1.3
" 16	265	14 12.9	14 07.2	+ 5.7	14 13.0	−0.1
July 3	282	13 13.4	13 05.4	+ 8.0	13 12.1	+1.3
" 5	284	14 49.6	14 43.2	+ 6.4	14 50.0	−0.4
" 8	287	12 19.4	12 12.2	+ 7.2	12 19.0	+0.4
" 15	294	13 02.9	12 56.9	+ 6.0	13 04.0	−1.1
" 20	299	12 07.9	12 03.7	+ 4.3	12 11.0	−3.1
" 22	301	13 46.6	13 41.5	+ 5.1	13 48.8	−2.2
" 27	306	12 54.4	12 48.3	+ 6.1	12 55.9	−1.5
" 29	308	14 32.7	14 26.7	+ 6.0	14 34.5	−1.8
Aug. 3	313	13 40.9	13 32.9	+ 8.0	13 41.0	−0.1
" 5	315	15 19.0	15 10.7	+ 8.3	15 19.0	0.0
" 6	316	11 10.1	11 01.9	+ 8.2	11 10.7	−0.6
" 11	321	10 18.5	10 08.7	+ 9.8	10 17.2	+1.3
Sept. 4	345	10 03.5	9 51.5	+12.0	10 01.5	+2.0
" 6	347	11 41.1	11 29.4	+11.7	11 39.6	+1.5
" 9	350	9 10.5	8 58.4	+12.1	9 08.7	+1.8
" 21	362	9 01.8	8 49.9	+11.9	9 00.9	+0.9
" 28	369	9 47.7	9 34.4	+13.3	9 45.9	+1.8
Oct. 1	372	7 19.1	7 03.5	+15.6	7 15.2	+3.9
" 5	376	10 33.1	10 19.2	+13.9	10 31.0	+2.1

		Rotation $=9^{\mathrm{H}}\ 55^{\mathrm{M}}\ 34^{\mathrm{S}}.0$			$9^{\mathrm{H}}\ 55^{\mathrm{M}}\ 34^{\mathrm{S}}.0$ $+t\times 0^{\mathrm{s}}.00209$	
Date.	Days.	T_0	*Ephemeris*	*Obs−Eph*	*Ephemeris*	*Obs−Eph*
1881		H M	H M	M	H M	M
Oct. 13.	384	7 08.2	6 54.9	+13.3	7 07.3	+0.9
" 23.	394	5 25.2	5 08.6	+16.6	5 21.6	+3.6
Nov. 1.	403	7 44.7	7 30.9	+13.8	7 44.5	+0.2
" 13.	415	7 37.9	7 22.3	+15.6	7 36.8	+1.1
" 16.	418	5 07.2	4 51.3	+15.9	5 06.0	+1.2
" 26.	428	3 22.8	3 04.9	+17.9	3 20.3	+2.5
Dec. 3.	435	4 07.0	3 49.4	+17.6	4 05.3	+1.7
" 8.	440	3 15.7	2 56.2	+19.5	3 12.5	+3.2
" 10.	442	4 53.2	4 36.0	+18.2	4 51.4	+1.8
" 12.	444	6 31.6	6 11.9	+19.7	6 28.5	+3.1
" 27.	459	3 54.0	3 32.2	+21.8	3 49.9	+4.1
" 31.	463	7 10.2	6 47.9	+22.3	7 05.9	+4.3
1881						
Jan. 10.	473	5 25.3	5 01.7	+23.6	5 20.6	+4.7
" 17.	480	6 08.2	5 46.3	+21.9	6 05.7	+2.5
" 27.	490	4 26.4	3 59.9	+26.5	4 20.1	+6.3
June 17.	631	15 17.5	14 43.6	+33.9	15 17.2	+0.3
" 20.	634	12 47.8	12 12.6	+35.2	12 46.5	+1.3
" 22.	636	14 25.8	13 50.4	+35.4	14 24.5	+1.3
July 28.	672	14 02.6	13 24.7	+37.9	14 02.7	−0.1
Aug. 2.	677	13 10.4	12 31.6	+38.8	13 10.1	+0.3
" 9.	684	13 55.5	13 16.2	+39.3	13 55.6	−0.1
" 24.	699	11 21.3	10 36.6	+44.7	11 17.7	+3.6
Sept. 5.	711	11 11.2	10 28.0	+43.2	11 10.5	+0.7
" 21.	727	14 20.4	13 35.0	+45.4	14 19.5	+0.9
" 22.	728	10 10.6	9 26.2	+44.4	10 10.8	−0.2
Oct. 7.	743	7 33.7	6 46.6	+47.1	7 33.1	+0.6
" 9.	745	9 11.8	8 24.5	+47.3	9 11.3	+0.5
" 24.	760	6 34.2	5 44.9	+49.3	6 33.5	+0.7
" 26.	762	8 10.6	7 22.7	+47.9	8 11.6	−1.0
Nov. 5.	772	6 26.2	5 36.3	+49.9	6 26.5	−0.3
" 9.	776	9 44.6	8 52.0	+52.6	9 42.7	+1.9
" 19.	786	7 59.0	7 05.6	+53.4	7 57.7	+1.3
" 21.	788	9 35.9	8 43.4	+52.5	9 35.8	+0.1
" 22	789	5 29.1	4 34.5	+54.6	5 27.0	+2.1
" 24.	791	7 06.6	6 12.4	+54.2	7 05.2	+1.4
Dec. 1.	798	7 53.1	6 57.0	+56.1	7 50.6	+2.5
" 4.	801	5 22.1	4 26.0	+56.1	5 20.1	+2.0
" 6.	803	7 00.6	6 03.8	+56.8	6 58.1	+2.3
" 14.	811	3 37.2	2 39.0	+57.6	3 35.0	+2.2
" 18.	815	6 53.4	5 55.2	+58.2	6 51.1	+2.3
" 23.	820	5 59.7	5 02.0	+57.7	5 58.6	+1.1
" 28.	825	5 07.1	4 08.8	+58.3	5 06.1	+1.0
1882						
Jan. 9.	837	4 56.7	4 00.3	+56.4	4 59.3	−2.6
" 11.	839	6 35.4	5 38.1	+57.3	6 37.4	−2.0
" 14.	842	4 05.7	3 07.1	+58.6	4 06.9	−1.2
Feb. 2.	861	4 41.8	3 43 2	+58.6	4 45.6	−3.8
" 4.	863	6 24.0	5 21.1	+62.9	6 23.8	+0.2
" 7	866	3 53.8	2 50.1	+63.7	3 53.2	+0.6
" 9.	868	5 31.5	4 28.0	+63.5	5 31.4	+0.1
" 14.	873	4 40.2	3 34.8	+65.4	4 39.0	+1.2
" 23.	882	7 03.4	5 57.2	+66.2	7 02.8	+0.6
Mar. 22.	909	4 19.8	3 09.0	+70.8	4 18.6	+1.2
" 29.	916	5 03.0	3 53.7	+69.3	5 04.3	−1.3

ROTATION OF ♃ FROM EQUATORIAL WHITE SPOTS.

T_0 = observed passage over the central meridian, reduced to Sept. 25, 1879.

The same reduction numbers were used for the equatorial spots as for the great red spot. The error introduced may amount to ± 0.1 minute.

No one period of rotation will satisfy the observations for the equatorial white spots. For the two spots observed in 1880, the motion was remarkably uniform, as the small residuals in the column (Obs − Eph) will show. But during 1881, the single spot, observed continuously for a period of 252 days, indicated sudden deviations in its apparent place, probably due to change in the shape of the object observed. The longitudes, as determined, were correct within one minute of time, but the comparison with the ephemeris shows a maximum displacement of sixteen minutes of time, or more than 3″ of arc at mean distance.

Rotation = $9^{\text{H}}\ 50^{\text{M}}\ 00^{\text{S}}.5$

Date.	Days	T_0	Ephemeris	Obs − Eph	Remarks.
1879		H M	H M	M	
Sept. 10...	−15	12 24.8	12 57.9	−33.1	From Sept. 10, 1879, to July 8, 1880, the exact Rotation period is $9^{h}50^{m}03^{s}.5$
" 20...	− 5	8 19.7	8 58.1	−38.4	
1880					
July 8...	287	12 15.3	12 15.3	0.0	
" 17...	296	12 36.7	12 36.5	+ 0.2	
" 24...	303	11 47.4	11 45.7	+ 1.7	
Aug. 4...	314	13 17.2	13 15.0	+ 2.2	
" 6...	316	14 24.3	14 26.1	− 1.8	
" 11...	321	12 26.6	12 26.0	+ 0.6	
Sept. 3...	344	11 06.7	11 06.6	+ 0.1	
" 10...	351	10 16.5	10 16.7	− 0.2	
" 24...	365	8 35.6	8 37.2	+ 1.6	
Oct. 1...	372	7 47.6	7 47.3	− 0.3	

Rotation = $9^{\text{H}}\ 50^{\text{M}}\ 09^{\text{S}}.8$

Oct. 28...	399	9 18.5	9 18.5	0.0
Nov. 2...	404	7 20.3	7 20.5	− 0.2
" 8...	410	10 53.7	10 52.9	+ 0.8
Dec. 2...	434	5 20.4	5 22.4	− 2.0
" 6...	438	7 50.0	7 43.9	+ 6.1
" 9...	441	4 40.4	4 35.1	+ 5.3
" 31...	463	7 44.2	7 43.7	+ 0.5
1881				
Jan. 30...	493	5 44.5	5 45.6	− 1.1

EQUATORIAL WHITE SPOTS.

H M S
9 50 09.8

Date.	Days.	$T_\circ$	*Ephemeris*	*Obs—Eph*	Remarks.
1881		H M	H M	M	
July 22...	666	13 40.3	13 40.4	− 0.1	
Aug. 9...	684	14 27.9	14 27.5	+ 0.4	
Sept. 1...	707	13 23.4	13 16.4	+ 7.0	
" 21...	727	15 16.9	15 14.4	+ 2.5	
Oct. 8...	744	10 47.5	10 31.5	+16.0	
" 18...	754	6 46.6	6 35.4	+11.2	
" 20...	756	7 56.3	7 45 9	+10.4	
Nov. 5...	772	7 27.3	7 22.3	+ 5.0	
" 9...	776	9 47.7	9 43.8	+ 3.9	
" 14...	781	7 50.9	7 46.0	+ 4.9	
" 21 ..	788	7 09.3	6 58.8	+10.5	
" 24...	791	4 03.3	3 49.9	+13.4	
" 26...	793	5 14.4	5 00.4	+14.0	
Dec. 7...	804	6 41.5	6 35.3	+ 6.2	
" 9...	806	7 50.7	7 45.8	+ 4.9	
" 10...	807	3 31.1	3 26.2	+ 4.9	
" 14...	811	5 52.0	5 47.7	+ 4.3	
" 23...	820	6 12.1	6 11.3	+ 0.8	
" 28...	825	4 13.8	4 13.3	+ 0.5	
1882					
Jan. 17...	845	6 15.7	6 11.5	+ 4.2	
" 22...	850	4 14.0	4 13.5	+ 0.5	
" 24...	852	5 24.0	5 24.0	+ 0.0	
" 29...	857	3 33.8	3 26.0	+ 7.8	
Feb. 2...	861	5 51.7	5 47.5	+ 4.2	
" 4...	863	6 58.3	6 58.7	− 0.4	
" 7...	866	3 52.1	3 49.7	+ 2.4	
" 9...	868	5 01.6	5 00.2	+ 1.4	
" 16...	875	4 25.6	4 13.1	+12.5	
Mar. 1...	888	7 00.4	6 58.2	+ 2.2	
" 22...	909	4 33.0	4 36.6	− 3.6	
" 31...	918	5 00.1	5 00.1	+ 0.0	

DRAWINGS OF JUPITER.

The accompanying sketches of the planet Jupiter exhibit the more marked phenomena seen on his disc, from September 1879 to March 1882.

September 20, 1879, shows the system of belts and the equatorial white spot.

October 15, 1879, shows the great red spot and the equatorial white spot nearly in conjunction.

July 3, 1880, shows the second satellite just entering on the red spot, at $15^h\ 43^m.5$, and nine minutes later, the satellite nearly over the center of the spot.

So soon as the satellite touched the end of the red spot, it formed a notch, as is shown in the drawing, and when completely on the red spot, it appeared apparently as white as when outside the disc of the planet.

The equatorial white spot is also shown following the red spot.

August 4, 1880, shows two oval white spots on belt No. 6, a small black spot on belt No. 2, and two equatorial white spots.

September 9, 1880, shows the red spot, and a peculiar spur under it, apparently joined to the equatorial belt; also a small black spot on belt No. 2.

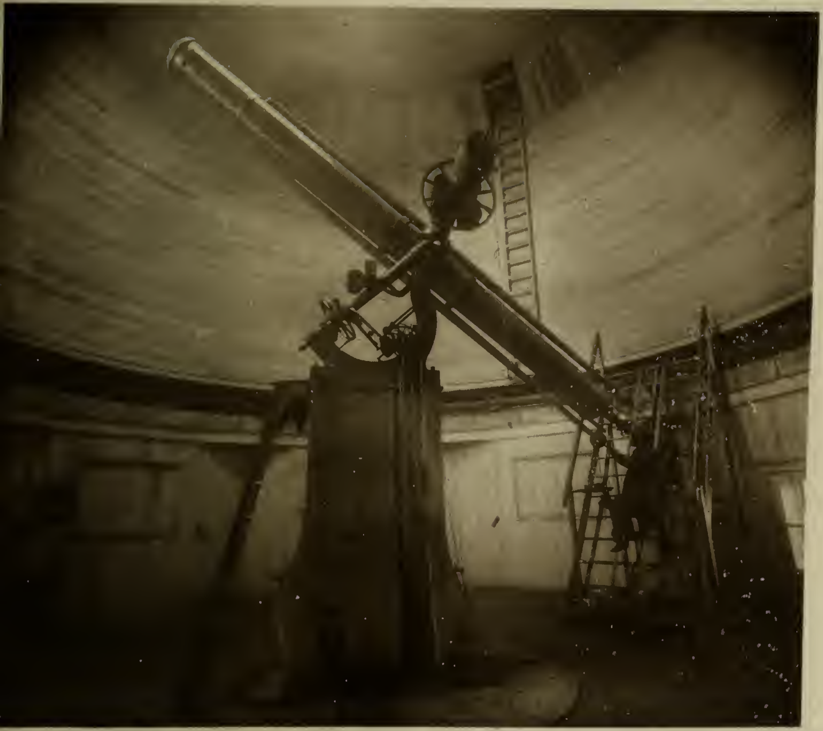
November 1, 1880, shows the shadow of the first satellite on the disc, and the shadow of the second satellite projected on the red spot. The shadow on the red spot was not quite as black as the shadow on the disc.

Two dusky spots are also shown on belt No. 3.

October 10, 1881, shows five oval white spots on belt No. 6.

December 1, 1881, shows the great red spot and the peculiar spur under it, as seen on September 9, 1880; also a minute black spot on belt No. 1, and two oval white spots south of the great red spot.

December 28, 1881, shows the drift of the two oval white spots in longitude, with reference to the great red spot;



THE EQUATORIAL,

DEARBORN OBSERVATORY, CHICAGO.

OBJECT GLASS.— { Focal Length, 23 feet.
Clear Aperture, 18½ inches.

also the principal equatorial white spot preceding the red spot, and a white equatorial rift following the spur.

October 25, 1881, shows four oval white spots on belt No. 6, and a minute white spot on the south margin of the equatorial belt.

March 22, 1882, shows the great red spot and the equatorial white spot nearly in conjunction.

In all of the sketches the whole disc of the planet has been represented as correctly as possible.

It will be noticed that belt No. 3 was dark during 1879 and 1880, but assumed a reddish hue in 1881 ; being very similar in color to the equatorial belt.

The shading about the poles is never seen as marked as it is usually represented in the drawings of this planet.

THE EQUATORIAL.

The Equatorial was constructed by Messrs. Alvan Clark & Sons, and has a focal length of 23 ft., and a clear aperture of 18½ inches.

The tube is of mahogany, mounted after the German style.

The polar-axis is supported by a cast-iron frame resting on a single block of stone 8½ ft. in height.

The Right Ascension Circle is 20 inches in diameter, divided to 30 seconds, and read by two microscopes to single seconds.

The Declination Circle is 30 inches in diameter, divided to 5 minutes, and read by two microscopes to 10 seconds.

On the rim of each circle, coarse divisions have been painted for quickly pointing the telescope. The Right Ascension may be readily set within 1 minute of time, and the Declination within 5 minutes of arc.

The driving clock is Bond's spring governor, which, with occasional repairs, performs very satisfactorily.

The parallel wire Micrometer was made by Clark & Sons. It is provided with six positive eye-pieces ; the powers of which, as determined by Mr. S. W. Burnham, are as follows:

No. 0,	120.	No. III,	390.
“ I,	190.	“ IV,	638.
“ II,	292.	“ V,	925.

The position circle is 8 inches in diameter, divided to 30 minutes, and provided with two verniers, which read to single minutes.

The adopted value of one revolution of the micrometer screw is 11″.42, and the thickness of the micrometer wire is 0″.30.

A second screw placed opposite the micrometer-head, carries both wires across the field when desired.

The wires are illuminated by a small gas burner, placed at the extremity of a short tube, inclined at an angle of 45 degrees to the plane of the circle.

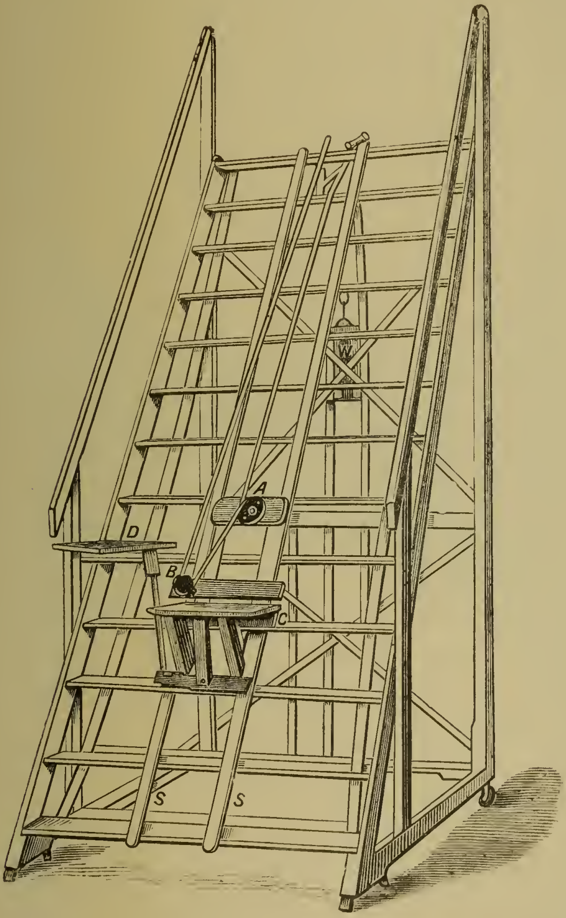
The finder telescope has a clear aperture of $3\frac{3}{4}$ inches.

The Equatorial Observing Chair now in use was devised in 1880. A description of it has been published in the Monthly Notices of the Royal Astronomical Society, the English Mechanic, and the Sidereal Messenger.

The mechanism is so exceedingly simple, that it readily commends itself to the practical Astronomer. The following is a brief description:

Over the center of a step-ladder, 11 ft. in height, and 5 ft. in width, are screwed two strips of pine, s s, two inches in width, which pass from the top to the bottom of the steps; the distance between them being about seven inches. A light wooden frame is made to slide on this track, to which the observing seat, c, is attached. The seat is 20 inches in length and 12 inches in depth. In order to keep it in place, the strips, s s, are beveled on the inside, with corresponding bevels in the sliding frame, analogous to the slide-rest of a lathe. The seat when in use is raised and lowered by the following device:

To the top of the steps, on the right-hand side, in the figure, is attached a woven cord $\frac{3}{8}$ of an inch in diameter, which is passed *once* around a fixed wooden drum, A, 5 inches in diameter, attached to the frame carrying the seat, thence over a loose pulley, B, near the seat, thence back again to the top of the steps, over a loose pulley, not shown in the figure, thence over the weight-pulley, W; the end being fastened on the right-hand side. The weight slides in vertical tracks, attached to the rear of the step-ladder, and is just sufficient to balance the seat.



The seat, therefore, is held in position simply by the torsion-friction of the cord around the fixed drum A, without the use of any clamp or stop. The whole weight of the seat and frame is about 15 lbs., and a very slight force, viz.: 10 lbs., will cause it to slide up the track when unloaded.

When seated in the chair, a slight pull downwards, on the rope to which the counterpoise is attached, causes it to descend any amount desired.

As the whole merit of our apparatus consists in the ease and celerity with which the observer may secure the proper elevation for the eye, it may be added that the seat is completely under control; it may be moved one inch or a foot, almost instantaneously, and in this respect is infinitely superior to any screw or rack motion.

For the upward movement it is necessary to rest one's weight on the steps.

As there are no ratchets or stops, but simply a rope wrapped around a smooth drum, the chair can be manipulated in the dark without difficulty. The cost of applying this apparatus to the step-ladder was about five dollars.

When using the micrometer, a small table, D, for holding the note-book, lamp, eye-pieces, etc., is attached on the side of the seat and may be removed at pleasure.

The step-ladder, itself, is mounted on castors and is easily shifted to any required position.

When micrometric measures are not in progress, the seat may be slid to the top of the steps, where it is out of the way, and the ladder may be used in the ordinary way without inconvenience.

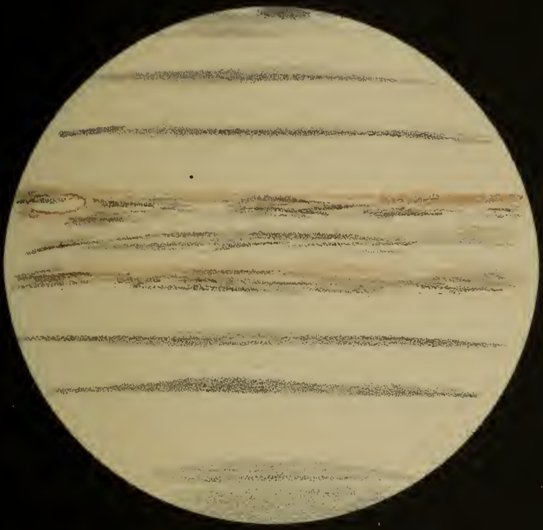
The following are the dimensions of our step-ladder and chair:

Length of steps, 5 ft.
Distance between the steps, 9¼ in.
Depth of step, 7½ in.
Height of ladder, 11 ft.
Depth of ladder, 6½ ft.
Size of upright frame, 3 in. by 1¾ in.
Size of hand-rail, 2½ in. by 1¾ in.
Seat, 12 in. by 20 in.
Table, 14 in. by 20 in.
Distance from seat to drum, D, 18 in.

A step-ladder built to conform to the radius of the telescope, and provided with a sliding seat similar to the one described, could be mounted on fixed tracks so as to be always at the right distance from the telescope, but we doubt whether it would be as convenient as one moving freely over the floor in any direction.

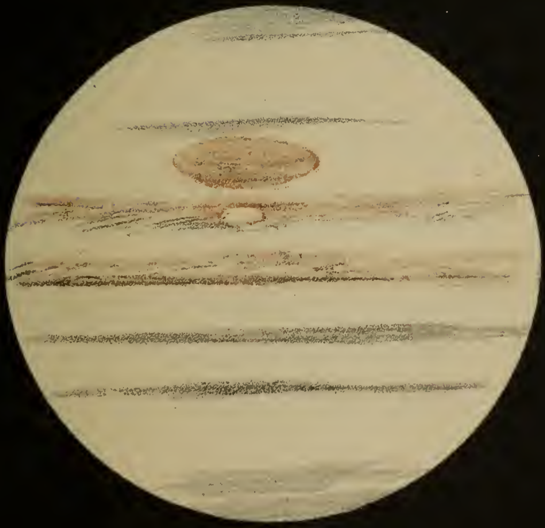
JUPITER

1879. Sept 20th. 9h.-45m.



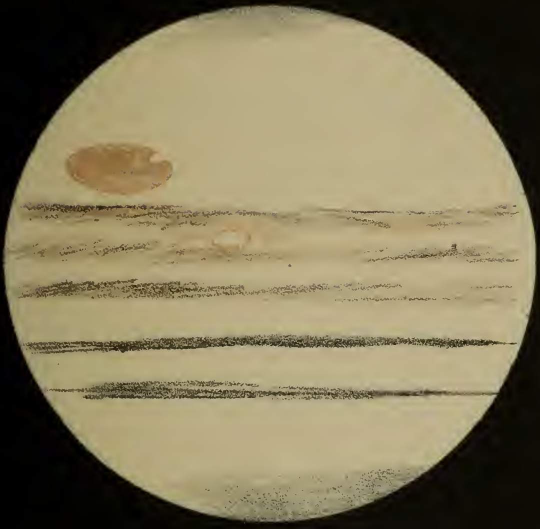
JUPITER

1879. Oct. 15th. 8h.-07m.



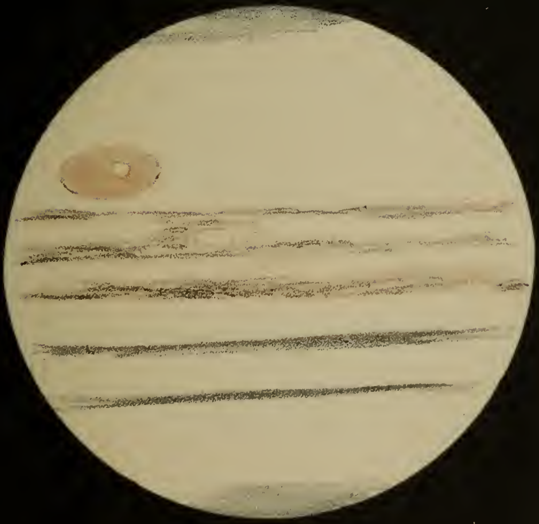
JUPITER

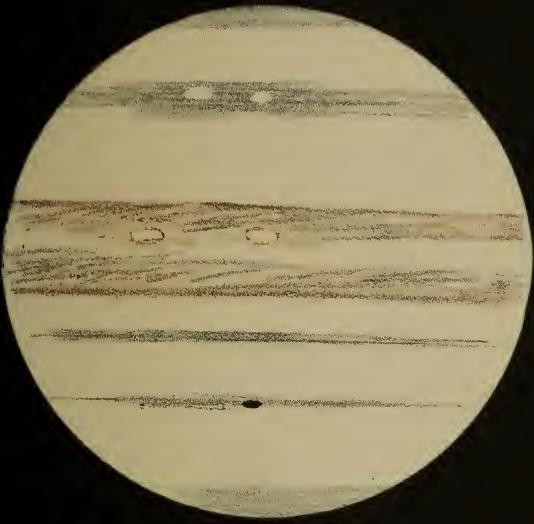
1880. July, 3rd·15h.-43-5m.



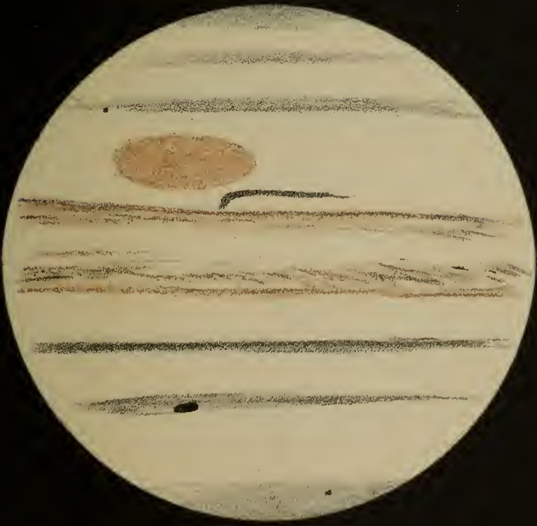
JUPITER

1880. July, 3rd·15h.-52m.



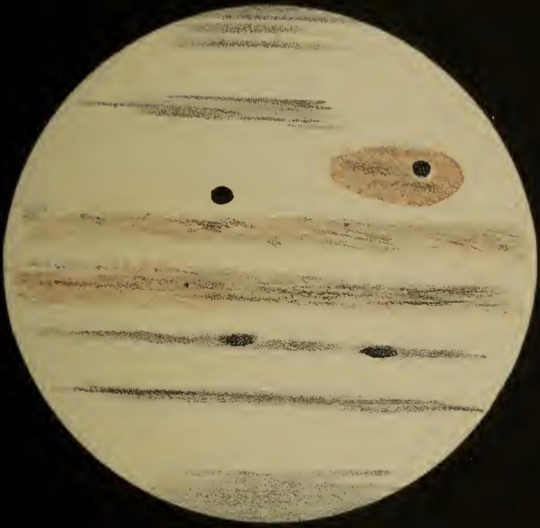


JUPITER
1880. Aug. 4th. 15h.-15m.

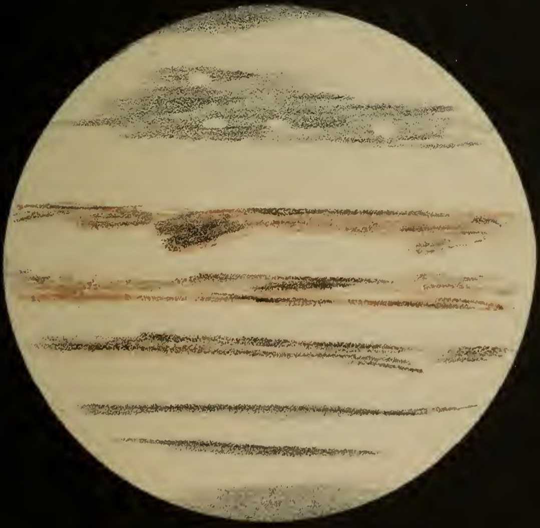


JUPITER
1880. Sept. 9th. 11h.-00m.

JUPITER
1880. Nov. 1st. 7h.–55m.

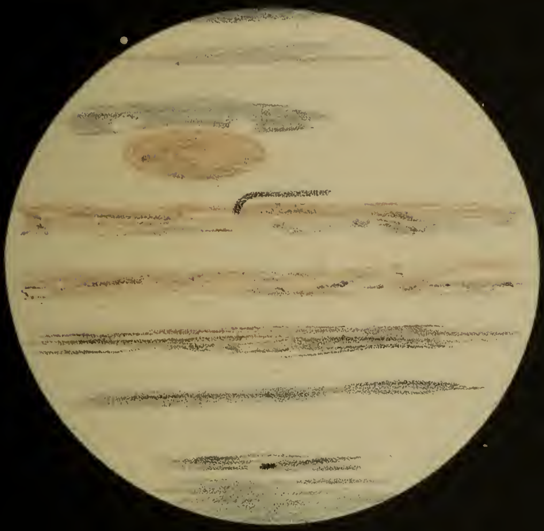


JUPITER
1881. Oct. 10th. 10h.–35m.



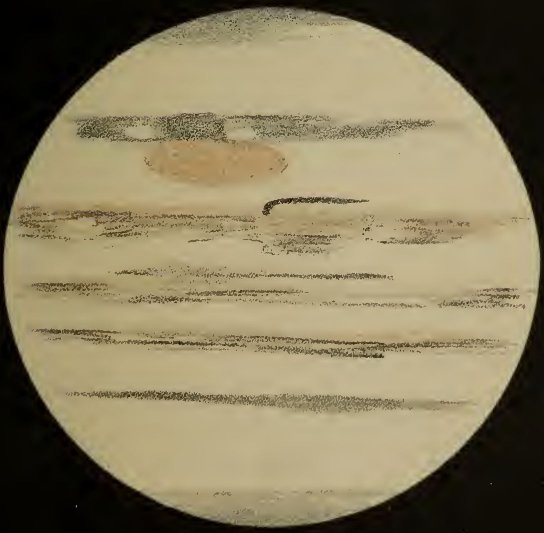
JUPITER

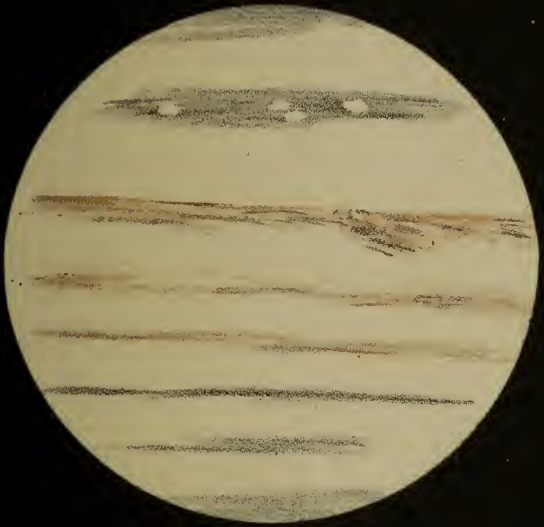
1881. Dec. 1st. 10h.--30m.



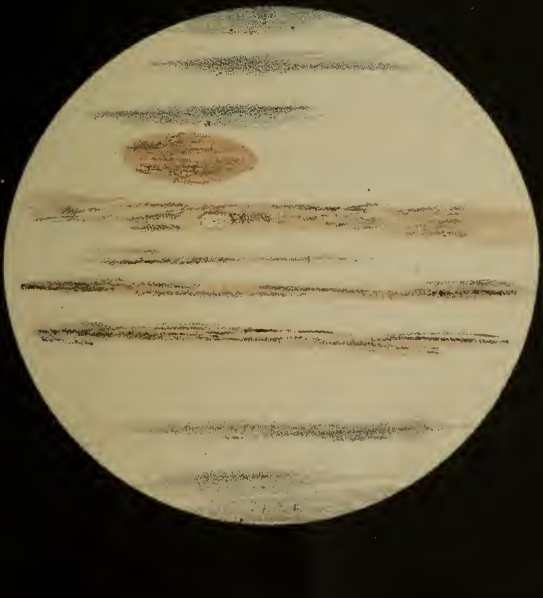
JUPITER

1881. Dec. 28th. 7h.--30m.





JUPITER
1881. Oct. 25th. 9h.–55m.



JUPITER
1882. Mar. 22nd. 7h.–25m.

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G. W. HOUGH,
Dearborn Observatory.

ANNUAL REPORT

OF THE

BOARD OF DIRECTORS

OF THE

Chicago Astronomical Society

TOGETHER WITH THE

REPORT OF THE DIRECTOR

OF THE

DEARBORN OBSERVATORY,

1883.

CHICAGO:
KNIGHT & LEONARD, PRINTERS.
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b

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" " 1886—Clinton Briggs, Henry W. Fuller, C. H. S. Mixer.

DIRECTOR OF OBSERVATORY.

Prof. G. W. Hough.

520.6
CH
1882/83

REPORT.

Annual Report of the Board of Directors
to the Chicago Astronomical Society:

Your directors beg to report that during the year they have aimed to continue such a conservative policy as would tend to promote the stability of the Society and its scientific usefulness.

At the beginning of the year the Hon. J. Y. Scammon resigned the office of President of the Society, to which he had been re-elected. We are sure that the members at large have heartily approved the resolutions which the Board then adopted, and which were printed in an appendix to the last Annual Report.

Mr. Scammon kindly consented to continue a supervision of the legal proceedings noted in that report. The following is his report relative thereto:

"Since the last Annual Report no action has been taken under the Bill of Interpleader filed by the Astronomical Society to enforce its rights in the litigation between the Chicago University, the Union Mutual Life Insurance Company and other parties. The Bill was demurred to by the Life Insurance Company, but the demurrer has not been argued, as it was thought it might better be disposed of on the general hearing of the case, which is now before the master in chancery, to take proof as between the University and the Insurance Company. Our counsel have no doubt that whatever may be the result as to the University, the rights and property of the Astronomical Society will be protected and sustained."

The contract with the city authorities for time service has been renewed for the current year.

A gas engine for furnishing power to turn the Observatory dome has been purchased, and the necessary machinery and fittings are being procured.

Such repairs have been made as seemed needful to the preservation of your property.

The Treasurer's report shows the receipts and expenditures for the year, and a cash balance of $1,302.64.

Prof. G. W. Hough, the Director of your Observatory, has prepared a summary of his observations and studies during the year, and those of others who have used your instruments, which is herewith submitted and made a part of this report.

Respectively submitted by the Directors.

C. H. S. MIXER,
Secretary.

Chicago, May 9, 1883.

REPORT.

To the Board of Directors of the
Chicago Astronomical Society:

Gentlemen,—The following brief report will exhibit the nature of the Astronomical work carried on at the Dearborn Observatory during the past year.

The instruments in constant use are the great equatorial, the Repsold meridian circle, recording chronograph, and the various standard clocks. All have been kept in first-class working order, by making the necessary repairs and adjustments when needed.

The furnishing of standard time to the City and to the Western Electric Company has been successfully performed during the past year.

I am happy to report that the transmission of time signals to the Fire-Alarm office, for the use of the city, has been maintained during the past twelve months without any interruption whatever.

The signal clock has been adjusted daily at 9 A.M., by comparison with the standard clocks and chronometer. And by means of the chronograph, it has been set exactly on the true time so indicated.

Whenever meridian observations could be secured on two or more days in any week, the signals have been practically correct, and when (owing to long continued cloudiness) observations were not possible, they have rarely been one-half second in error; so that in point of precision our time service will compare favorably with the best systems elsewhere.

The standard mean-time clock, placed in the City Fire-Alarm office, has been kept as nearly correct as was practicable. Through the courtesy of the superintendent, the error of this clock is telegraphed to the Observatory daily.

When the accumulated error amounts to two-seconds, I have attended to its adjustment. Its rate during the past year has been remarkably steady, and it has required but little personal attention.

The going of the mean-time clock at the Observatory, has been greatly improved by re-adjusting the compensation.

The Repsold meridian circle has been used between May 5, 1882 and May 5, 1883 on 140 days, for time observations, or an average of rather more than two and one-half days each week.

All transit observations for time are made with the chronograph; five wires being recorded. These observations are usually made during daylight.

The instrumental errors, collimation and level, are invariably determined by observing the reflection of the middle wire over mercury, when the telescope is directed to the nadir, which is preferable to using the spirit level. Very soon after my connection with this Observatory, I remarked the ease with which nadir observations could be made here. At most observatories, without some special appliance for supporting the artificial horizon, nadir observations are at times difficult if not impossible. I presume the freedom from earth tremors here is due to the nature of the soil.

For time purposes, the azimuth is obtained from combining observations of standard stars north and south of the zenith. During the first week in December, 1882, I exchanged time-signals by telegraph on three nights with Prof. C. H. McLeod, stationed at Winnipeg, B. A., for the purpose of determining the longitude of that station for the transit of Venus.

EQUATORIAL.

The work with the great equatorial, as in former years, has been confined to such classes of observations as are difficult or impossible with smaller telescopes.

The following objects were specially studied:

(1) The Great Comet of 1882.
(2) Difficult double stars.
(3) The planet Jupiter.
(4) Miscellaneous Observations.

THE GREAT COMET.

The great comet of 1882, which appeared so suddenly and was of such unusual brilliancy, was first observed through the great equatorial on the morning of October 4. For two days previous to this date the towers of the university hid it from view.

The head or nucleus, with its surrounding envelope, when first-seen presented the shape of an enormous turnip with the base toward the sun. Near the larger end the condensation was sufficient to cause it to appear as a round disc, surrounded by an envelope of less luminous matter.

The length of the nucleus and envelope was 25″, and the greatest breadth 9″.

The actual length was therefore 13,500 miles and the breadth nearly 5,000 miles.

The tail, notwithstanding the moonlight, could be traced for about 25°, corresponding to an actual length of 50 millions of miles.

Subsequent to this time a good deal was said in the newspapers about the breaking up of the nucleus into three separate and distinct fragments.

As such a phenomenon would be of great interest, the observations made here may throw some light on the subject.

October 5 was cloudy. On the morning of the 6th the nucleus was 26″ in length and 6″ in breadth, and the condensation was not confined to one portion. The principal condensation was the same as before, and preceding and following at nearly equal intervals there were two other centers of condensation, and near the extreme preceding end, there were three or more small centers, but each and all of these masses were connected with matter of less density, so that there was no actual separation.

From October 4 to November 20, micrometer measures and sketches of the nucleus and envelope were made on twelve days. Subsequent to the 6th of October, the changes in the head were not so marked, as usually three centers of condensations were visible. As the comet receded from the sun, however, the head gradually increased in length from 25″ on October 4 to 139″ on November 20, or 13,500 miles in the former case to 86,000 miles in the latter.

On February 27 and March 6, 1883, the comet was observed, and although it was very faint, yet there appeared to be three centers of condensation, as on the 6th of October, but they were, as formerly, connected with matter of less density. All the observations made here confirm me in the belief that no complete separation took place between the parts of the head.

DOUBLE STARS.

During the past year I discovered sixty-six new double stars, most of which are difficult objects, and can only be measured when the seeing is good.

It may be proper to remark here, that for this class of work, not more than one observing night in three is suitable for such observations.

In searching for DeArrest's comet, six new nebulæ were discovered, three by Mr. S. W. Burnham and three by myself.

The companion to Sirius, a difficult object, was measured on eleven nights, giving for the mean of the measures, as follows:

Date—1883. 120

Position Angle	39°.7.
Distance	9″.02.

Mr. S. W. Burnham's measures for the same epoch are mean of ten observations.

Position Angle	40°.1
Distance	9″.05

This interesting binary system is becoming more difficult every year as the distance between the components is diminishing about 0″.3 annually. I presume in a few years more it will be entirely out of the reach of any except the largest telescopes.

JUPITER.

The planet Jupiter, as heretofore, has been carefully observed, and micrometer measurements made on all salient spots and markings for the determination of their Longitude and Latitude.

During the past four years the principal object of interest has been the great red spot first noticed in 1878.

This object, which was formerly of a reddish brick color, during the present opposition has gradually grown paler, until at the present time it is barely visible.

A short time since, it was stated in the newspapers that it had already disappeared, but this is a mistake, as we secured observations for Longitude April 28 and May 5. I presume, however, owing to its extreme faintness, it will not continue visible much longer in any telescope.

This spot has been remarkable in its stability. Since the first observation made here in September, 1879, to the present time, it has not changed very materially in length, breadth, outline or Latitude. There has been, however, a slow retrograde drift in Longitude, or in other words, a gradual increase in the apparent time of rotation of the planet on its axis.

The rotation period in 1879 was $9^h\ 55^m\ 34^s.0$. In last year's report it was shown that the rotation period increased directly with the time elapsed. The approximate "mean" rotation period deduced from the present opposition is $9^h\ 55^m\ 38^s.4$, showing that the drift has continued.

The following mean results for the past four years will be of interest:

	1879.	1880.	1881.	1882.
Length	12″.25	11″.55	11″.30	11″.83
Breadth	3″.46	3″.54	3″.66	3″.65
Latitude	−6″.95	−7″.14	−7″.40	−7″.52

It appears from a comparison of these figures that the spot has gradually drifted south 0″.5 of arc, or about twelve hundred miles. The length appears to have varied nearly one second of arc, during the four years. While the spot has remained nearly stationary in Latitude, the south edge of the great Equatorial Belt has gradually drifted south during the present opposition, until it is nearly coincident with the middle of the spot. But what is remarkable, the two do not blend together, but are entirely distinct and separate. A depression has formed in the edge of the Belt, corresponding in shape to the oval outline of the spot, the distance between the two objects being about 1″ of arc. That portion of the Belt following the spot first began to drift, forming a bend near the position occupied by a curious offshoot, seen at various times in 1880 and 1881. The non-blending of the two objects would seem to indicate that they are composed of matter having repellent properties, similar to two clouds charged with the same kind of electricity. July 3, 1880, I saw the curious phenomenon of a satellite in transit, cross the red spot. It is well known that satellites in crossing the bright disc of Jupiter, disappear when a short distance from the edge. During the present opposition I observed a satellite transit over the densest portion of the Equatorial Belt, but it disappeared the same as when projected on the bright portion of the disc. On the contrary, when the satellite was seen on the red spot it appeared essentially as bright as when off the disc. From these observations we may infer that the matter is not in the same condition for the two objects.

In the years 1664-5-6, a great spot was observed by Hook and Cassini. It was situated one-third of the semi-diameter of the planet south of the equator in latitude 6″. Its diameter was about 1-10 the diameter of Jupiter or about 8000 miles.

This spot appeared and vanished eight times between the years 1665 and 1708. From 1708 to 1713 it was invisible; the longest time of its continuing to be visible was three years, and the longest period of its disappearing was five years.

I am not aware that this ancient spot has been observed in modern times unless it is identical with the one now under discussion.

If theancient observation, extending over half a century, refers to the same object, we would naturally infer that it was a portion of the solid body of the planet ; being sometimes rendered invisible by a covering of clouds.

Owing to the rapid rotation of the planet on its axis, the appearance of the disc changes from hour to hour. After an interval of two or three hours we may have under view quite a new set of phenomena.

The statement universally made in text books on astronomy, that in the course of a few hours new belts are formed, etc., is not warranted from the nature of the observations.

Observers even at the present time, do not always realize that they are looking at a globe and not at a plane surface.

As objects are brought in view on the following limb by the rotation of the planet, they are infinitely small and as they are gradually brought nearer the middle of the disc they increase in size, attaining a maximum and then gradually diminish, until they are finally lost near the preceding limb.

The great red spot has been seen through our telescope when its length was only 1″ of arc, and as it passed across the disc it attained a maximum of 15″, or one-third the diameter of the planet. As we pass from the equator toward the poles the apparent transit of an object across the disc becomes slower and slower, while at the poles it would be stationary.

From those considerations you may infer that statements of change in size or shape of objects on the disc of Jupiter, in the course of a couple of hours, are not legitimate deductions drawn from the actual phenomena.

EQUATORIAL BELTS.

The great Equatorial Belt which remained without material change in size or position in 1879, 1880 and 1881, during the present opposition has drifted south nearly 2″ of arc. And from October, 1882, to February, 1883, the north edge was not well defined, so that the belt appeared to extend to B_3 or north latitude + 8″.

ELLIPTICAL WHITE SPOTS.

The small oval white spots observed on Belt No. 6, in 1880 and 1881, were quite numerous during the past opposition. Owing to their number and the difficulty of observation, their identification is somewhat uncertain, but they appeared generally to drift in a retrograde direction at the rate of 70 miles per hour.

A single spot south and following the great red spot was observed on five nights, from September 1 to October 14, 1882. It had an average drift in the direction of the planet's rotation of about 10 miles per hour.

EQUATORIAL WHITE SPOTS.

The equatorial white spot which was first observed in 1879, was again visible during the past opposition. The rotation period as deduced last year, viz.: $9^h\ 50^m\ 09^s.8$, satisfies the observations.

Another spot in latitude + 3″, appears to give a rotation of $9^h\ 49^m\ 33^s$.

There were numerous minute white spots and markings near the equatorial region, which were observed, but are not yet fully discussed.

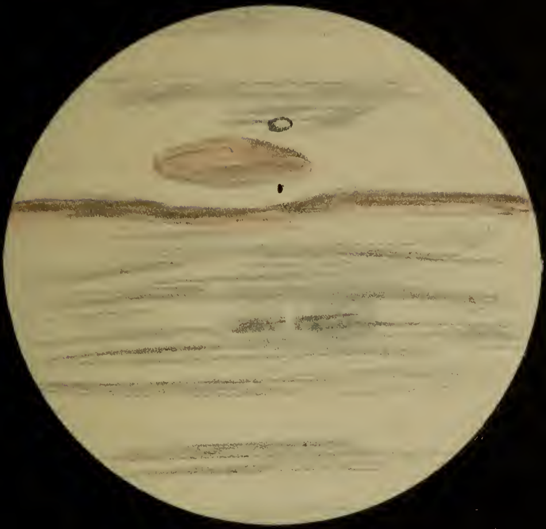
It is a curious fact that these equatorial spots should drift for years with the enormous velocity of 260 miles per hour, if they are nothing more than clouds in the atmosphere of the planet.

The following is a summary of the observations on Jupiter:

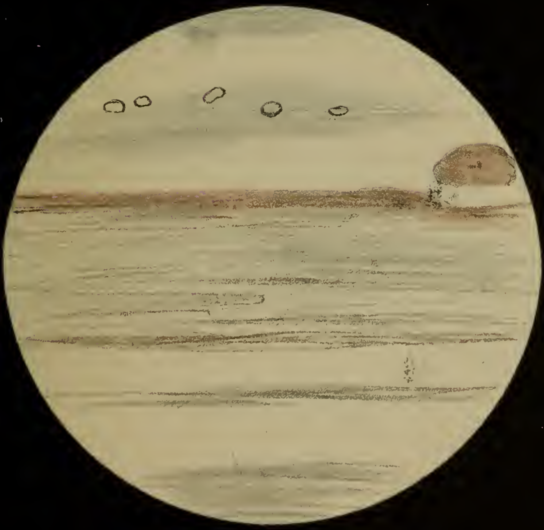
GREAT RED SPOT.

Longitude	30	nights;	232	measures
Latitude	8	"	64	"
Length	12	"	48	"
Breadth	3	"	12	"
Total			356	"

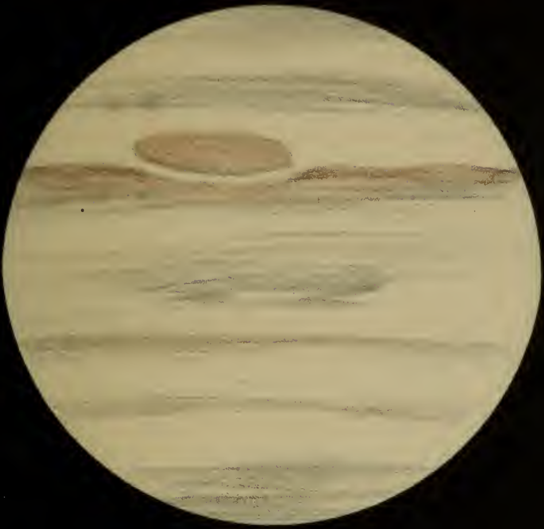
JUPITER
1882, Oct. 14th. 17h.-20m.



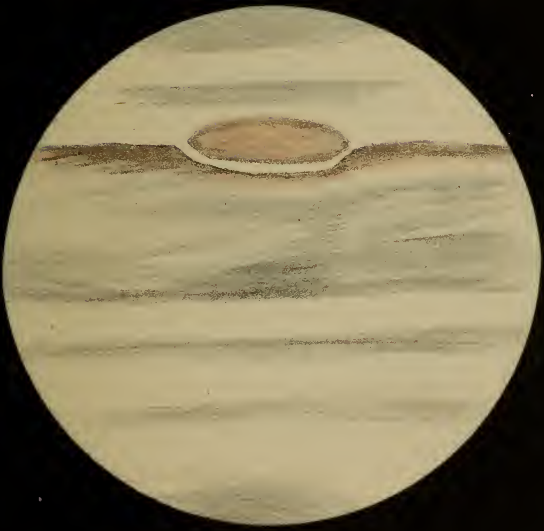
JUPITER
1882, Dec. 24th. 8h.-55m.



JUPITER
1882, Dec. 29th. 10 h.-02 m.



JUPITER
1883, Feb. 20th. 8 h.-18 m.



EQUATORIAL BELT.

Observed on twenty-four nights:

Position of the south edge	80	measures
Latitude	96	“
Width	44	“
Total	220	“

EQUATORIAL WHITE SPOTS.

Observed on fifty nights:

Longitude	268	measures
Latitude	100	“
Total	368	“

POLAR SPOTS AND OTHER MARKINGS.

Observed on fourteen nights:

Longitude	100	measures
Latitude	20	“
Total	120	“

Being a total of 1,064 micrometer measurements.

DRAWINGS OF JUPITER.

The accompanying sketches of the planet Jupiter exhibit the salient features of the disc. No attempt has been made to represent the minute detail of the markings in the equatorial region.

The sketches show the gradual drift of the south edge of the equatorial belt, toward the south.

October 14, 1882, shows the great red spot, a small white spot south, and the equatorial belt, extending to belt No. 3.

December 24, 1882, shows the belt system, and white spots on belt No. 6.

December 29, 1883, shows the red spot and the belt system.

February 20, 1883, shows the depression in the equatorial belt, conforming to the outline of the great red spot.

TRANSIT OF VENUS.

That rare and interesting phenomenon, the transit of Venus, December 6, last, was observed here under very favorable atmospheric conditions.

The times of external and internal contact at ingress, were observed by Mr. S. W. Burnham through the finder, and by myself with the great equatorial, using a diagonal and twelve-inches aperture.

Shortly after first contact a grayish light was noticed around that portion of the disc of Venus farthest from the sun, and at six minutes after the first contact the whole disc of Venus was conspicuously visible, both in the finder and the great equatorial.

As second contact approached no black drop or other phenomenon was seen, except that due to the atmosphere of the planet, which caused a haziness at the point of contact of the limbs of Venus and the sun, and a complete separation did not take place for nearly thirty seconds after the two limbs were apparently tangent to each other.

After making the contact observations, in connection with Mr. S. W. Burnham and Dr. H. D. Garrison, a number of dry-plate photographs were taken, showing the planet Venus projected on the disc of the sun.

Heretofore astronomical photography, for measures of precision, has proved almost entirely a failure, owing principally to the fact that the object photographed is not absolutely at rest, but vibrates from side to side, due to the disturbance in the earth's atmosphere. Now in landscape photography when it is desired to represent objects in motion, viz.: a race horse, or a bird flying, it is necessary to make a very short, or what is technically called an instantaneous exposure; then the object is photographed for that instant the same as if at rest.

Now it may be readily inferred that the same principle when applied to astronomical purposes should be equally successful. Hence, we should expect a short exposure would give sharper outlines than a long one.

In making the transit of Venus photographs, the eye piece was removed from the telescope tube and a small camera fixed in its place. In front of the camera was a sliding shutter, having an opening across of 1-16 of an inch in width. When the shutter was unlocked a rubber spring shot it across the tube, successively exposing the whole disc of the sun.

The passage of the slit across the sun's disc occupied 1-39 of a second, and the equivalent exposure for any part of it was only 1-1600 of a second.

I may add that the exposure was very much shorter than was used by the government.

The photographs taken here gave a very sharp outline for the discs of the sun and Venus.

These experiments show conclusively that astronomical photography will be most successful when the time of exposure is reduced to the smallest duration possible.

On account of clouds the last contacts could not be observed.

As heretofore, during the year Mr. S. W. Burnham has had the use of the telescope for double-star observations. He has also materially aided me in my own work. He reports as follows: The measurement of difficult and interesting binaries, including the following: β Delphini (β 151). δ Equulei (*O* Σ 535). 85 Pegasi (β 733). 40 Eridani (Σ 518). S 503, Sirius. He also reports the discovery of three new nebulæ and a number of new double stars.

The Observatory, as usual, has been open to members of the Astronomical Society on Thursday evenings, and by special arrangements, to classes in astronomy from the city high schools and elsewhere.

During the winter term instruction in practical and theoretical astronomy was given to the senior class of the university.

G. W. HOUGH,
Director.

May 9, 1883.

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ANNUAL REPORT

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DIRECTOR OF OBSERVATORY.

Prof. G. W. Hough.

520.6
C44
1885

REPORT.

Annual Report of the Board of Directors
to the Chicago Astronomical Society:

Your Board of Directors beg leave to report that, as for several years past, their chief endeavor and duty has been to so conduct the affairs of the Society as to promote, in some fair degree, its usefulness to astronomical science, and to keep its expenses strictly within its income.

The report of the Treasurer will show you the receipts and expenditures of the two years now ending, and that he has on hand a cash balance of $1,368.87.

The arrangement with the city for time service has been continued, and recently arrangements for furnishing observatory time to the large new clock in the tower of the Board of Trade building have been completed.

The report of Hon. J. Y. Scammon, who is in charge of the Society's litigation in connection with the suits between the Union Mutual Life Insurance Company and the Chicago University, is herewith presented.

The books in the Society's library have been carefully catalogued by Prof. Hough and Mr. Colbert.

The Society has met with a great loss in the death of the Hon. W. H. Wells, who was its honored Vice-President from the date of its organization to the time of his death. Suitable action thereon was taken by your directors at a special meeting held January 27, 1885. Mr. Elias Colbert was unanimously chosen Vice-President, to fill the vacancy created by the death of Mr. Wells.

At the annual meeting of 1884 it was found that both your President and Vice-President were unable from illness to attend the meeting, and the financial disturbances at the East were absorbing the minds of our business men. After two attempts to hold a meeting, it was decided to adjourn without action, as under the by-laws of the Society all officers would hold over until their successors were elected.

Prof. G. W. Hough has continued Director in charge of your Observatory. His report is presented herewith, and made a part of this report.

Respectfully submitted by the Board of Directors.

C. H. S. MIXER,
Secretary.

CHICAGO, May 20, 1885.

REPORT OF HON. J. Y. SCAMMON.

The intervening suit in Chancery against the Union Mutual Life Insurance Company of Maine, instituted in the Circuit Court of the United States for the Northern District of Illinois, by this Society, to protect its property on the University campus, in consequence of the proceedings of said Company to enforce its mortgage against the University, its grounds, and the property upon the same, came on to be heard before Judge Henry W. Blodgett, and was unexpectedly decided against the Society. The case was imperfectly presented, owing to the death of the Hon. Thomas Hoyne, and the sickness and absence of Mr. Scammon when the final proofs were taken.

Mr. Driggs, who had diligently and ably attended to his duties as the solicitor in the case, was unable, from a want of personal knowledge of the particular facts in the case, to rebut the testimony unexpectedly given by Dr. Burroughs upon the subject of the purchase of the instruments, and the subscriptions of moneys to purchase the same and build the Dearborn Observatory Tower.

Mr. Scammon was called upon to make the concluding argument for the Astronomical Society, immediately upon his return from New York, and was obliged to submit his argument upon the case as presented in the printed testimony, without opportunity to master or rebut the same. The decision of Judge Blodgett was based mainly upon the testimony of Dr. Burroughs, and was so unexpected that Mr. Scammon stated to the Court that the case had been so misrepresented in the testimony of Dr. Burroughs that he should feel compelled to ask leave to file a bill of review, in order to present the abundant proofs, the real facts, which had become necessary in consequence of the unexpected and extraordinary testimony of Dr. Burroughs, which he had not seen until called upon to argue the case. The Judge at once said he might make a motion for a rehearing, and present affidavits in support of his motion. This was done. The affidavit of Mr. Scammon, contradicting the testimony given by Dr. Burroughs, as to the contributions for the purchase of the instruments and the building of the Observatory, giving a full and complete history of the whole transaction, with original and historical documents, supported by the affidavits of all the living original contributors known to Mr. Scammon, who, at the first inception of the Society, in Garrett block, on the 16th of December, 1862, by their subscriptions constituted themselves the original Astronomical Association, to-wit: D. J. Ely, Thomas B. Bryan, Charles G. Wicker, and Philip Wadsworth (in addition to Mr. Scammon), and of John K. Pollard and Charles N. Holden, at the date of these subscriptions trustees of the University and original life directors of the Society, of the secretaries of the board of trustees of the University at the time of the original subscriptions and the building of the tower, Rev. Justin A. Smith, and Cyrus Bentley, and of Prof. Elias Colbert, who, as reporter for the Chicago *Times* and *Tribune*, was familiar with the early history of the Society, and, from his official connection with it since, an undoubtedly reliable witness; of H. C. Ranney, one of our directors, and the Treasurer of the Society, and of William W. Boyington, the architect of the Observatory building, also a life director, and of the Rev. Galusha Anderson, the President of the University, and the Rev. Dr. W. H. Ryder, showed so manifestly that Dr. Burroughs' testimony was erroneous, that the Judge granted a rehearing of the case, and the counsel for the Insurance Company offered at once to surrender all the instruments and removable property, if the Society would give up its claim to the tower and the use of the campus. This offer was declined, and the counsel for the Society instructed to prosecute the suit for the property of the Society.

This decision was made not only because of the confidence of the directors in the claims of the Society, but because they regard the Society as trustees for the subscribers and the public, whose duty as such trustees it is to protect and defend the title of the Society to all the property created or procured by the funds sacredly placed in the treasury of the Society by the public-spirited promoters of the study of the heavenly bodies.

A sense of duty forbids us to abandon any of the property except upon a decree of a court of last resort. We may be excused if in this connection we allude to the fact, recognized in scientific journals, that "for more than ten years this institution was in possession of the largest refracting telescope in existence," and though telescopes of greater focal length "have since been built, there seems to be the best of reasons for doubting whether any other instrument at present in existence is surely superior to the Chicago refractor for efficient astronomical work." (*Science*, New York.)

Our Observatory has accomplished work which has given the Society a character and its instrument a reputation throughout the astronomical and scientific world. We cannot abandon it, or suffer ourselves to be deprived of it, so long as any effort on our part is required to demonstrate our fidelity to a noble scientific trust.

Judge Blodgett allowed till the 10th of May instant for the taking of the new testimony on the part of the Society, and till June 1 to the Insurance Company to rebut it.

Mr. Scammon has devoted a great deal of time to the preparation and obtaining of the affidavits, and the taking of the testimony, and on the part of the Society it is now all in. It is not yet known whether any rebutting testimony will be presented.

In addition to the testimony of the witnesses who gave affidavits, is the deposition of Ezra B. McCagg, for many years and during the time of the transactions involved in this litigation, a trustee of the University and a life director of the Society, which is very pronounced as to the distinct and separate character of the University and its property, and that of the Astronomical Society and its property.

The case will be finally heard before Judge Blodgett probably early in June.

REPORT

OF THE

DIRECTOR OF THE DEARBORN OBSERVATORY.

To the Board of Directors of the
Chicago Astronomical Society:

Gentlemen,—The following brief report will exhibit the nature of the astronomical work carried on at the Dearborn Observatory during the past year.

The instruments in constant use have been kept in good working order by making the necessary repairs.

During the year standard time, as heretofore, has been furnished to the city of Chicago daily. The signal clock has transmitted its beats to the fire-alarm office without interruption.

From May 13, 1884, to May 13, 1885, meridian observations for time have been made with the Repsold meridian circle on 154 days, or an average of two and one-half days each week.

The longest interval between successive observations was seven days.

The signal clock has been compared with the standard mean-time clocks at 9 A.M. of each day, and adjusted when necessary. The time signals have generally been correct within two-tenths of a second, and during protracted cloudiness the accumulated error has been inside of one second.

About two years ago I began to adjust the compensation of the old M. T. clock, which was very greatly overcompensated. I have finally reduced the height of the mercury column 0.78 inch, and the compensation for temperature is now approximately correct. The going of this clock could undoubtedly be further improved by a more substantial mounting.

The standard clock placed in the city fire-alarm office has received my personal attention daily, and has been adjusted when necessary.

During my absence of two weeks last summer Prof. Elias Colbert kindly took charge of the time service and made the necessary observations.

Some time since, I began the construction of a Printing Chronograph, which has recently been put to actual work. The ordinary recording chronograph furnishes a series of broken lines, and the time of an observation is ascertained by measuring the space between the seconds mark made by the clock and that indicating the observation.

When systematic meridian work is done, the labor necessary to convert the chronographic record into numbers is very considerable. The pecuniary value of this labor in a first-class observatory would probably amount to at least $1,000 annually.

The object of the printing chronograph is to obviate all this labor, by making at once a printed record of the time of each observation.

The apparatus consists of:

1. A system of clock work carrying a type-wheel with fifty numbers on its rim, revolving once every second; one, two, or parts of two numbers being always printed, so that hundredths of seconds may be indicated. This train is primarily regulated to move uniformly by the Frauenhaufer friction balls, and secondarily by an electro-magnet acting on the type-wheel and controlled by the standard clock. This train is entirely independent, and can be stopped at pleasure without interfering with the other type-wheels.

2. A system of clock work, consisting of two or more shafts, carrying the type-wheels indicating the minutes and seconds. The motion of this train is also governed by an electro-magnet, controlled by the standard clock, operating an escapement in a manner analogous to the action of an ordinary clock, every motion of the escapement advancing the type one number.

There are three type-wheels indicating minutes, seconds, and hundredths of seconds.

The integer seconds are advanced at every oscillation of the standard pendulum, and the minute at the end of each complete revolution of the seconds wheel.

The type were engraved on solid brass disks, which were previously spaced on a gear cutter.

In front of the type-wheels is placed an electro-magnet of one-ohm resistance, the armature of which carries three flexible arms, to which the printing hammers are attached. Under the printing hammer is a spool of paper two inches in width. One end of the paper is carried over the tops of the type and passed between two brass rollers. In the rear of the type-wheels small wooden rollers, covered with cloth, rest lightly against their rims for the purpose of inking the type.

The type-wheels are readily set to indicate the time of the standard sidereal clock.

The apparatus may be put in operation for recording observations in two or three minutes, including the preparation of the inking rollers and the setting of the type-wheels.

The impression is made by means of the electro-magnet without stopping any of the type-wheels. The records, therefore, may follow each other as rapidly as the electro-magnet can be operated.

The battery employed for printing consists of three small storage cells, equivalent to the same number of Grove elements. These cells are charged by means of a small gravity battery of eight elements, the whole arranged in series, so that the connections need not be disturbed.

If the impression is made when the seconds are in the act of changing, parts of two numbers are printed; and in case the hundredths read 96 to 98, the smaller second is the correct one. There can be no ambiguity. By means of a duplicate key, a blank space of any width may be left on the paper fillet between the records for different stars.

It is my intention to connect a small revolving cylinder with the train carrying the hundredths of seconds type-wheel, so that whenever an observation is printed, it will at the same time be recorded on the small cylinder. By this method there will be a complete check against any possibility of error. It will not be necessary to examine individual observations, since if at the close of work the zero of the sheet is correct, we may take it for granted that no seconds have been lost during the progress of the records.

It may be added that this is the only printing chronograph in use.

EQUATORIAL.

The work with the great equatorial, as in former years, has been confined to a few special subjects.

(1) Difficult double stars.
(2) The planet Jupiter.
(3) Miscellaneous observations.

DOUBLE STARS.

During the past year I have discovered and measured thirty-nine new double stars, a number of which will probably prove to be interesting objects.

The companion to Sirius, as in former years, has been measured on ten nights, with the following results:

Date — 1885. 197.

Position Angle	32°.7.
Distance	7″.96.

Since 1880 the distance has diminished 2″ of arc, the rate of decrease being now a little more than 0″.5 annually.

When the seeing was suitable for micrometer work, I have as yet found no special difficulty in measuring it.

THE PLANET JUPITER.

The planet Jupiter has been systematically observed, in relation to the physical phenomena seen on his surface. As in former years, the principal object of interest was the great red spot. This object, which during the previous two oppositions was quite faint, has become more conspicuous; so much so as to be readily seen with moderate optical power.

The first observation was made on September 25, 1884, when it was quite faint. As the planet approached nearer the earth it increased in distinctness, and in the early part of November it was sharply outlined, exhibiting the same shape that it did in 1879.

During the severe cold of the past winter the seeing was almost invariably too poor for any critical study of minute detail; but on February 27 the spot showed a very curious change in structure. It appeared as an elliptical ring, the middle being white, or rather the general color of the disc of the planet. An observation was made on February 2, when the following notes were made: Seeing fair; outline sharply defined; shape same as formerly; paler than the equatorial belt, but reddish in color. It would appear from these observations that the ring was formed between February 2 and 27.

The ring shape of the spot continued without material change for a month or more; then it began to gradually close up, and at the date of the last observation, May 15, there was only a faint strip of white in the middle.

An elliptical ring, very similar to the one described, and occupying the same position in latitude, was observed in 1869 and 1870; but seems to have disappeared, as we have no record of a spot in this locality until 1878, when the present red spot was detected. It is possible, however, that our present spot is identical with that of 1869, as has been suggested by Mr. Denning.

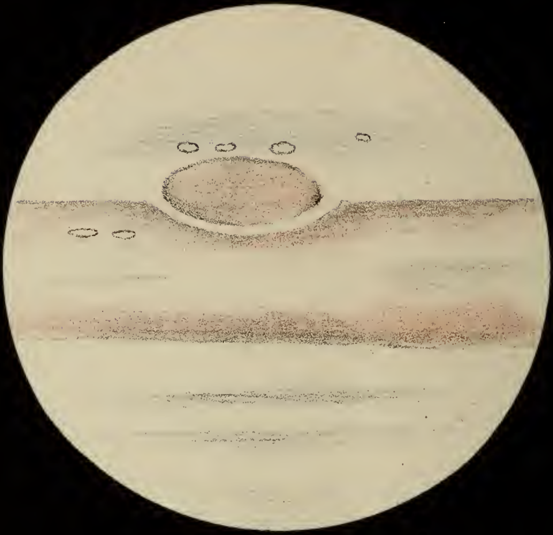
The cause of the change in structure in this object is difficult to explain.

If the spot were a hollow globular mass, and it should be covered with clouds, the color would be most intense at its outer margin, because at that point we would look through the greatest thickness of material, and hence it would present the appearance of a ring. As the covering of clouds passed off or became thinner, the ring would gradually close up, and the same color would be seen over its whole surface.

This spot is remarkable in respect to its permanency on the disc of the planet. It is now nearly seven years since it was first detected, during which period it has been readily

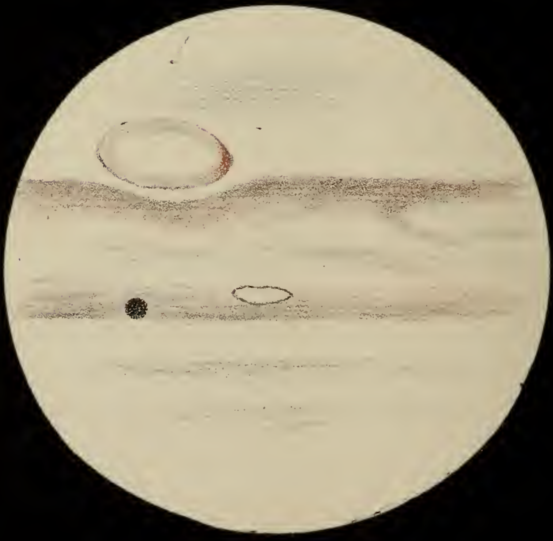
JUPITER

1884, Nov. 7th. 16h.-39m.



JUPITER

1885, Feb. 27th. 9h.- 25m.



seen with the Chicago telescope whenever the planet was far enough from the sun for observation. This is the longest period of visibility of any spot which has heretofore been observed on the surface of the planet.

The "mean" rotation period of the planet, from observations on the red spot, from 1882 to 1884 was $9^h\ 55^m\ 38^s.35$.

During the past opposition the rotation period shows a slight increase, indicating a retrograde drift in longitude.

The following rotation periods have been deduced:

1884.	Sept. 25 to Dec. 3, 69 days	$9^h\ 55^m\ 44^s.0$
	Dec. 3 to Feb. 2, 61 days	$9^h\ 55^m\ 40^s.1$
1885.	Feb. 2 to April 4, 61 days	$9^h\ 55^m\ 39^s.1$
	April 4 to May 15, 41 days	$9^h\ 55^m\ 38^s.7$
	May 15 to June 29, 45 days	$9^h\ 55^m\ 42^s.0$

The "mean" rotation period from September 25, 1884, to June 29, 1885, is $9^h\ 55^m\ 40^s.4$.

The "mean" rotation period from September 25, 1879, to June 29, 1885, comprising 2.104 days, or 5,086 rotations, is $9^h\ 55^m\ 37^s.40$.

The outline of the red spot is the same as it was when first observed by us in 1879, but the length appears to be a little less than for previous years.

The following summary will show the changes from year to year in the length, breadth, and latitude of the spot:

	1879.	1880.	1881.	1882.	1883.	1884.
Length..	$12''.25$	$11''.55$	$11''.30$	$11''.83$	$12''.29$	$11''.26$
Breadth .	$3''.46$	$3''.54$	$3''.60$	$3''.65$		$4''.30$
Lat.	$6''.95$	$7''.14$	$7''.40$	$7''.52$	$6''.35$	$6''.50$

The depression in the equatorial belt under the red spot, which was formed in 1882, has continued, but is gradually being obliterated.

The following is a synopsis of the changes in the position of the belt from year to year:

	1879.	1880.	1881.	1882.	1883.	1884.
Lat. N. edge	$+2''.59$	$2''.33$	$2''.16$	$2''.44$	$2''.58$	$+4''.95$
Lat. S. edge	$-4''.18$	$-4''.71$	$4''.75$	$6''.36$	$5''.80$	$-4''.69$
Width.....	$6''.77$	$7''.04$	$6''.91$	$8''.80$	$9''.30$	$10''.03$

During the present opposition the displacement has been most marked on the north edge of the belt.

ELLIPTICAL WHITE SPOTS.

A number of small white spots were observed on belt 6 in latitude —9″ south, at different times from March 1, to July 6, 1885.

These objects are always difficult to observe, and owing to their numbers, their identification was somewhat uncertain. The observations show, however, as in former years, that the general surface of the planet has the same rotation as is indicated by the great red spot.

EQUATORIAL WHITE SPOTS.

The principal equatorial white spot which has been observed since 1879 was not so conspicuous as in former years. The first observation of this object during the past opposition was on September 28, 1884, and the last on June 16, 1885. At times the spot disappeared, or was too faint and indistinct for accurate observation.

The rotation period deduced from the extreme observations was $9^h\ 50^m\ 08^s.2$, but the old value, $9^h\ 50^m\ 09^s.8$, satisfies all of the observations the best.

Another equatorial white spot in latitude +1″.03, following the old spot, $4^h\ 30^m$ in longitude, was quite conspicuous, and was observed from October 13, 1884, to June 8, 1885, a period of 238 days. The rotation period deduced from this spot was about $9^h\ 50^m\ 09^s.2$.

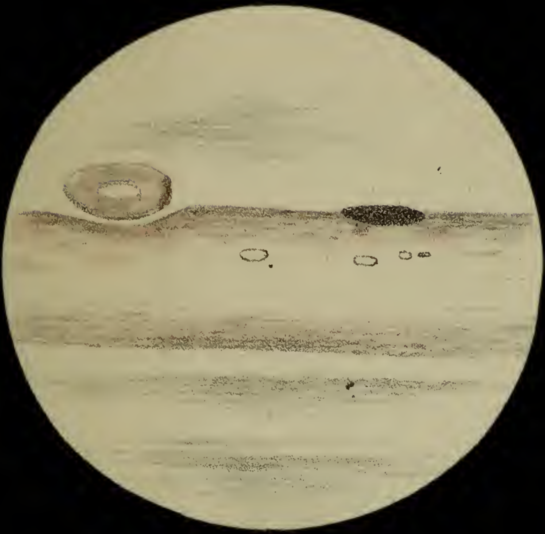
Two oval red spots were observed on the south margin of the equatorial belt. The most conspicuous one was 6″ in length, and followed the great red spot about $1^h\ 46^m$ in longitude. The other was 1″ in length, and followed the red spot $3^h\ 30^m$ in longitude.

The rotation period deduced from the observation of these spots was $9^h\ 55^m\ 43^s.8$ and $9^h\ 55^m\ 43^s.3$ respectively; being very nearly the same as that given by the great red spot.

On the north margin of the equatorial belt, two ill-defined

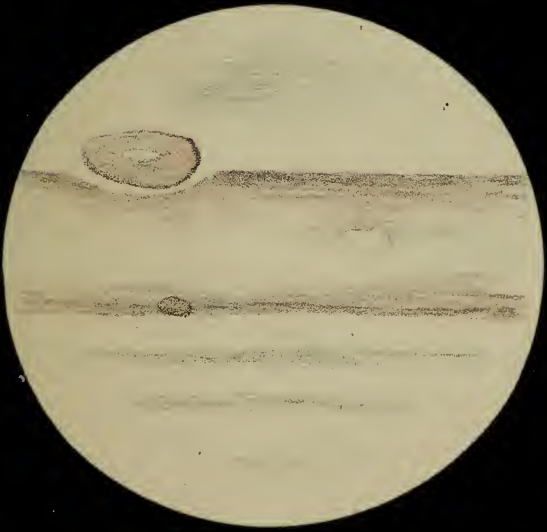
JUPITER

1885, Apr. 26th. 7h.-42m.



JUPITER

1885, May. 15th. 8h.- 09m.



white spots, or notches, were observed occasionally, the one preceding the great red spot about $3^h\ 35^m$ in longitude, and the other following $3^h\ 40^m$ in longitude.

The rotation periods from these spots were nearly the same as that given by the great red spot.

The phenomenon on the surface of Jupiter is of a complicated nature, and offers a wide field of study for the practical astronomer. That it is in some degree periodic is highly probable. As the axis of the planet is nearly perpendicular to the ecliptic, the meteorological changes will necessarily be slow, and may possibly be repeated in a Jovian year, or about twelve of our years.

DRAWINGS OF JUPITER.

The accompanying sketches of the planet Jupiter exhibit the salient features seen on his disc. We have not attempted to give the detail of structure in the equatorial region; but all the salient markings, both in magnitude and position, have been based on micrometer measurement.

November 7, 1884, shows the great red spot, equatorial white spots, the white spot south, and the belt system.

February 27, 1885, shows the ring form of the great red spot, a white spot, and the shadow of the fourth satellite, and the belt system.

April 26, 1885, shows the ring form of the red spot, the long red spot on the south margin of the equatorial belt, equatorial white spots, and the belt system.

May 15, 1885, shows the ring form of the red spot as nearly effaced; a small spot on the north margin of the equatorial belt, and the belt system.

The following is a summary of the observations on Jupiter:

GREAT RED SPOT.

Longitude	19	nights;	160	measures
Latitude	9	"	72	"
Length	8	"	64	"
Breadth	4	"	32	"
			328	"

EQUATORIAL BELT.

Observed on fifteen nights:

Position	15 nights;	120 measures
Latitude N. E.	5 "	40 "
Latitude S. E.	4 "	32 "
Width	8 "	64 "
		256 "

EQUATORIAL WHITE SPOTS.

Observed on thirty-one nights:

Longitude	31 nights;	248 measures
Latitude	5 "	40 "
		288 "

POLAR SPOTS AND OTHER MARKINGS.

Observed on seventeen nights:

Longitude	17 nights;	136 measures
Latitude	5 "	40 "
		176 "
Total		1,048 measures

The partial eclipse of the sun of March 16 was observed for last contact. During the progress of the eclipse, Mr. S. W. Burnham, Dr. H. D. Garrison, and myself made a number of dry-plate negatives of the phenomenon. The most successful was that taken through red glass. The outline was remarkably sharp and well defined.

The Observatory, as usual, has been open to members of the Astronomical Society on Thursday evenings, and by special arrangements, to classes in astronomy from the city high schools and elsewhere.

During the present term instruction in theoretical and practical astronomy has been given to the senior class of the University.

G. W. HOUGH,
Director.

May 20, 1885.

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ANNUAL REPORTS

OF THE

BOARD OF DIRECTORS

OF THE

Chicago Astronomical Society

1885/6
1886/7

TOGETHER WITH THE

REPORT OF THE DIRECTOR

OF THE

DEARBORN OBSERVATORY,

FOR

1885 AND 1886.

WITH PAPERS BY

PROFS. SAFFORD (NEBULÆ), COLBERT (LUNAR APSIDES
AND SIRIUS), AND HOUGH (DOUBLE STAR
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Robert Warren,	A. C. Thomas,	G. C. Walker,
H. C. Ranney.	C. H. S. Mixer.	Murry Nelson.

DIRECTOR OF OBSERVATORY:

Prof. G. W. Hough.

5206
CH
1885/7

REPORT, 1885-6.

*Annual Report of the Board of Directors
to the Chicago Astronomical Society:*

The Directors beg leave to report that the affairs of the Society present very few new features to note, outside of litigation now happily at an end.

The annual report of the Treasurer shows a balance on hand of $966.01.

The Society during the past year has lost by death two of its Directors, *viz.:* John Forsyth and P. H. Willard; and of its Life Members, D. A. Jones, J. S. Rumsey, and C. H. Walker.

The services rendered to this Society by John Forsyth and P. H. Willard demand more than a passing notice; both took a deep interest in its success, and were always among the very few punctual in their attendance at our meetings.

The contract with the city for time-service has been continued during the present year.

A contract has also been consummated with a leading jewelry firm in this city to supply it with standard time from our Observatory; and negotiations are now in progress with the Board of Trade, which it is hoped will increase the income and usefulness of our Society.

Your Directors would recommend that the list of about one hundred nebulæ, discovered by Prof. Safford while in charge of the Observatory, and now in manuscript, be printed with the annual report; this list shows what was done by him with the equatorial, and, although somewhat old, should be preserved and disseminated. It is due to him that, as some of these objects have since been rediscovered by others, proper credit should be given to him.

Prof. E. Colbert has made some interesting calculations on the elements of the lunar orbit, which we recommend be printed with the reports.

The Directors also suggest that a portrait of our late Vice-President, William H. Wells, be procured, and placed in the rooms of the Observatory.

The Society is to be congratulated that the litigation referred to above is at last ended. A decree of court places the Society in absolute possession of its instruments, books, clocks, and the house in which the meridian circle is located; but does not give us any title to the tower or any portion of the real estate.

The report of our legal adviser, Hon. J. Y. Scammon, which accompanies this, will give you a full statement of our rights in the premises.

In this connection, we would recommend that the incoming Executive Committee be intrusted with full power to determine and establish the status of this Society in its future connection with the University of Chicago, should the latter body carry out its proposed reorganization.

At this meeting three Directors will have to be elected, to serve for three years; and vacancies will have to be filled for one Director in place of P. H. Willard, whose term expires in 1887; and one in place of John Forsyth, whose term expires in 1888.

The report of your Director, Prof. G. W. Hough, is also submitted, and made a part of this report.

On behalf of the Directors,

HENRY C. RANNEY,

Secretary.

Chicago, May 12, 1886.

REPORT, 1886-7.

Annual Report of the Board of Directors
to the Chicago Astronomical Society:

The Directors in presenting their annual report submit but little of encouragement in the situation of the Society. Through delay in procuring certain necessary data, the report of the Society for 1885-6 has not been published; and as this meeting came very soon after the required information was received, we have thought it advisable to defer action, and publish this and last year's proceedings together.

The annual report of the Treasurer shows a balance on hand of $640.52; his statement is submitted as a part of this report.

The city has allowed the appropriation for time-service; and the Society may be congratulated that the work at the Observatory has been maintained under, to us, very discouraging circumstances.

Through the kindness of the Union Mutual Life Insurance Company, the present owners of the University property, we have been permitted to occupy our old rooms and the tower, subject, however, to a sixty days' notice to quit, which we may look for at any time.

This fact has made it necessary for your Directors to take steps to procure other quarters, and to this end we invited proposals for a permanent location for our instruments.

We have received an offer from a religious body to purchase our instruments, but this proposition your Directors respectfully declined, believing that they had no power or right to make such disposition of the property.

The Directors have had offers from Englewood and the universities at Evanston and Lake Forest, to provide a site and erect buildings for the use of the Society; also, offers of land in the public parks on which to erect necessary buildings. These offers are, for the present, held in abeyance, in the hope that there may yet be found among our public-spirited citizens those who will provide a permanent endowment, and thereby retain the location and management of the Observatory under our own control.

In the meantime, they recommend that this whole matter be referred to the incoming Board of Directors.

During the past year, the Society has lost one of its members by death, Mr. W. N. Sturges.

At this meeting, the Society will have to elect three Directors, to serve for three years, in place of Messrs. H. A. Johnson, G. C. Walker, and Murry Nelson, whose terms expire.

The report of Prof. Geo. W. Hough, the Director of the Observatory, is submitted as a part of this report.

On behalf of the Directors,

HENRY C. RANNEY,
Secretary.

CHICAGO, May 10, 1887.

REPORT
OF THE
DIRECTOR OF THE DEARBORN OBSERVATORY.

To the Board of Directors of the
Chicago Astronomical Society:

GENTLEMEN:—The following statement will show the progress of the astronomical work carried on at the Dearborn Observatory during the past two years.

As heretofore, standard time has been furnished daily to the city of Chicago and the Board of Trade. Some months since Messrs. Giles Bros. were also connected with the time-line.

The time signals have been sent continuously without interruption, and the standard M. T. clock in the office of the fire-alarm telegraph has been kept as close to the correct time as was practicable. The error of this clock has usually been inside of two seconds.

The time signals have been practically correct, except on a few occasions after protracted periods of cloudiness, when the accumulated error has amounted to one second.

Meridian observations for time have been made on 196 days in 1885 and 205 days in 1886, distributed in the different months as follows:

	1885.	1886.			1885.	1886.
May,	16	20		November,	15	16
June,	17	20		December,	18	15
July,	18	23	1887.	January,	14	12
August,	10	9		February,	19	14
September,	12	17		March,	19	20
October,	20	20		April,	18	19

This gives an average time determination every two days.

The error of the signal clock has been determined whenever observations were made, and adjusted when necessary. During periods of cloudiness it has been compared daily with the other clocks and chronometer.

During my absences of two weeks each year, Prof. Colbert again kindly took charge of the time-service and made the necessary observations.

The Observatory is indebted to Messrs. J. B. Mayo & Co. for the loan of a clock, which is regulated for sidereal time, and is used for operating the chronograph.

The printing chronograph, which was put in operation in 1884, has been remodeled and permanently mounted. The probable error of any impression is found to be less than ± 0·02 sec. This instrument is now exclusively used for recording meridian observations and for the comparison of clocks. Even when used in this limited manner, the making of meridian observations becomes a luxury.

A catalogue of the library has been compiled by Prof. E. Colbert and myself, and contains the titles of upward of eleven hundred volumes and pamphlets.

The work with the great equatorial, as in former years, has been confined to a few special subjects:

(1) Difficult double stars.
(2) The planet Jupiter.
(3) Miscellaneous observations.

DOUBLE STARS.

During the past two years I have discovered and measured 130 new double stars, the majority being difficult objects, and a considerable number of which will probably prove interesting, owing to the closeness of the components.

In the northern hemisphere, among stars of the 8th magnitude and brighter, but few equal pairs having a distance as great as 1″ remain to be catalogued; but for those having a distance of less than 0″.5, probably a very large number yet remain undiscovered.

Of the 130 pairs mentioned above, 45 pairs have a distance less than 0″.5, while only 11 pairs have a distance between

0″.5 and 1″; and the remainder belong to the class of stars having very minute companions.

For observations of this kind the most favorable atmospheric conditions are necessary, and hence but comparatively few observing nights are suitable either for measures or new discoveries.

I have recently published in the "Astronomische Nachrichten" a catalogue of 209 new double stars, including 550 micrometer measures.

This catalogue contains 50 pairs having a distance less than 1″. The catalogue pair No. 36 will probably prove a binary system.

The companion to Sirius, as in former years, has been measured on twelve nights in 1886 and seven nights in 1887.

The weather during the past winter and spring has been unusually unfavorable for observation. It is the first year that I have had any difficulty in securing observations of Sirius on as many nights as was desirable. On only one night was the companion conspicuous, when it was easily visible with the highest power. As the distance between the primary and satellite, however, grows less it becomes more difficult to observe, and I presume in a few years more it will require the best telescope and most favorable atmospheric conditions to see it at all.

The following is a comparison of my observations for each year, with the ephemeris of Prof. E. Colbert, computed in 1880 and published in the Annual Report for 1881:

Date.	P.	S.	Eph.	Eph.	Oh-Eph.	Oh-Eph.
1880.168	49°.6	9″.87	47°.8	10″.3	+ 1°.8	— 0″.4
1881.260	45°.3	9″.60	45°.5	9″.9	— 0°.2	— 0″.3
1882.127	43°.1	9″.30	43°.1	9″.45	— 0°.0	— 0″.2
1883.120	39°.7	9″.02	40°.4	8″.85	— 0°.7	+ 0″.2
1884.179	36°.7	8″.51	37°.2	8″.2	— 0°.5	+ 0″.3
1885.197	32°.7	7″.96	33°.5	7″.4	— 0°.8	+ 0″.5
1886.144	28°.7	7″.21	28°.8	6″.5	— 0°.1	+ 0″.7
1887.195	23°.7	6″.78	22°.4	5″.6	+ 1°.3	+ 1″.2

From this comparison it is seen that the position angles are well represented, but the distances appear to be in error.

SATURN.

During the opposition of 1885-6, the planet Saturn was frequently examined, when the seeing was unusually good, for markings by which to determine rotation.

During the month of February and following, a faint marking was noticed on the outer ring, which hitherto has not been seen here, at least during the past seven years. As the planet has been carefully examined at previous oppositions to detect this marking, which is always given in the drawings of the planet, I am strongly of the opinion that it is not a permanent division in the ring, as has been supposed, but a periodic phenomenon.

JUPITER.

The planet Jupiter has been systematically observed, with reference to the physical phenomena on his surface. As in former years, the object of general interest is the great red spot.

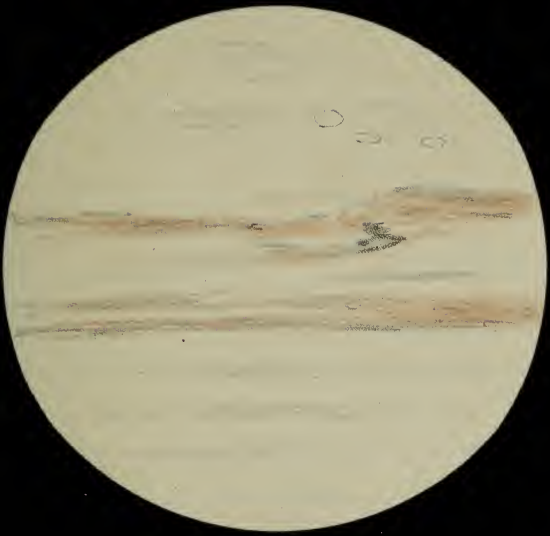
The outline, shape, and size of this remarkable object has remained without material change from the year 1879, when it was first observed here, until the present time. According to our observations, during the whole of this period it has shown a sharp and well-defined outline, and at no time has it coalesced or been joined to any belt in its proximity, as has been alleged by some observers.

During the year 1885, the middle of the spot was very much paler in color than the margins, causing it to appear as an elliptical ring. The ring-form has continued up to the present time. While the outline of the spot has remained very constant, the color has changed materially from year to year. During the past three years it has at times been very faint, so as barely to be visible.

The persistence of this object for so many years leads me

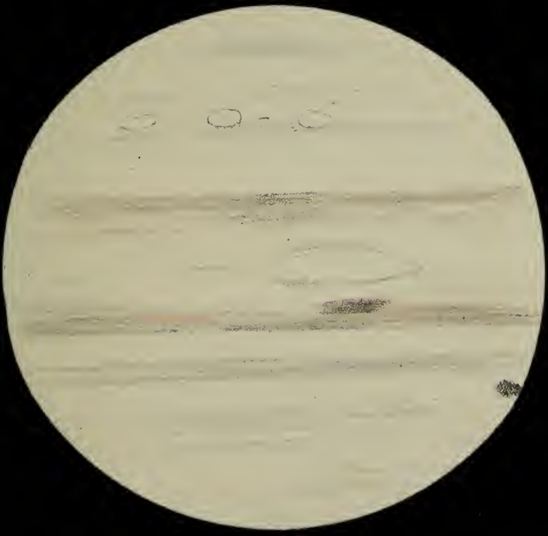
JUPITER

1886. March. 5th. 10h. - 45m.



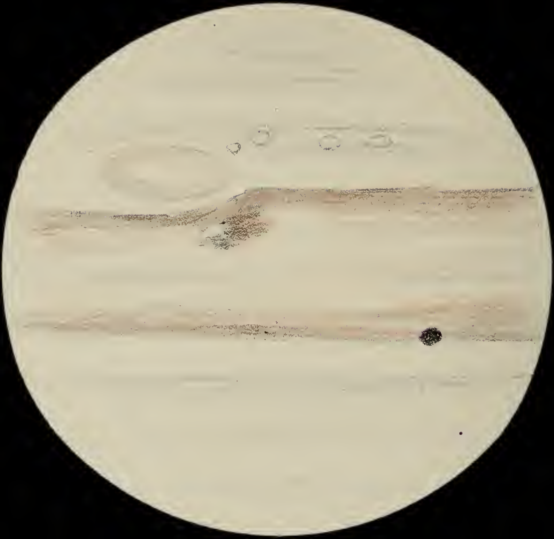
JUPITER

1886. March. 6th. 10h. - 08m.



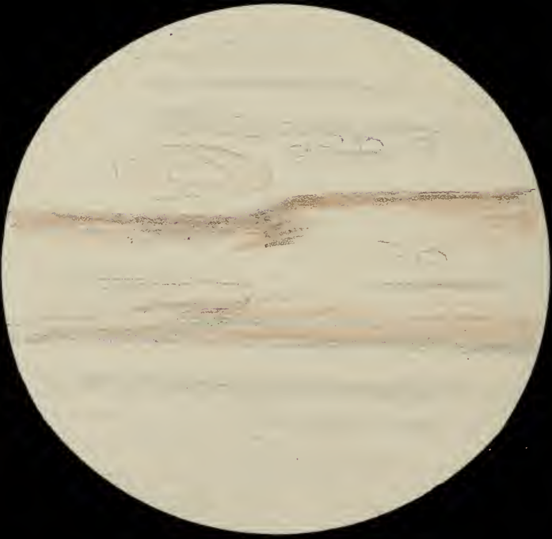
JUPITER

1886. May. 2nd. 9h.-30m.



JUPITER

1886. May. 7th. 8h.-08m.



to infer that the formerly-accepted theory, that the phenomena seen on the surface of the planet are atmospheric, is no longer tenable. The statement so often made in text-books, that in the course of a few days or months the whole aspect of the planet may be changed, is obviously erroneous.

The rotation period of Jupiter from the red spot has not materially changed during the past three years. The "mean" period, 1884-5, was $9^h\ 55^m\ 40^s.4$. Marth's ephemeris for the present year is based on a period of $9^h\ 55^m\ 40^s.6$. The mean correction to this ephemeris is now (May, 1887) only about minus 7 minutes, indicating a slightly less value.

A number of equatorial white spots were systematically observed in 1886; but, owing probably to the low altitude of the planet, they have not been so conspicuous during the present opposition.

The oval white spots on the southern hemisphere of the planet, 9″ south of the equator, have been systematically observed at every opposition during the past eight years. They are generally found in groups of three or more, but are rather difficult to observe. The rotation period deduced from them is nearly the same as from the great red spot.

These spots usually have a slow drift in longitude of about 0°.5 daily in the direction of the planet's rotation, when referred to the great red spot; corresponding to a rotation period of 20 seconds less than the latter.

The following is a summary of the observations on Jupiter:

GREAT RED SPOT.

1886.	Nights.	Measures.	1887. Nights.	Measures.
Longitude,	22	176	20	160
Latitude,	10	80	6	48
Length,	7	56	2	16
Breadth,	4	32	1	8
	Total,	344	Total,	232

EQUATORIAL BELT.

	1886. Nights.	Measures.	1887. Nights.	Measures.
Position,	16	80	13	65
Latitude,	11	88	10	80
Width,	11	88	9	72
	Total,	256	Total,	217

EQUATORIAL WHITE SPOTS.

	1886. Nights.	Measures.	1887. Nights.	Measures.
Longitude,	33	264	20	160
Latitude,	14	112	5	40
	Total,	376	Total,	200

POLAR SPOTS AND OTHER MARKINGS.

	1886. Nights.	Measures.	1887. Nights.	Measures.
Longitude,	8	64	10	80
Latitude,	6	48	10	80
	Total,	112	Total,	160

DRAWINGS OF JUPITER.

The accompanying sketches of the planet Jupiter exhibit the salient features seen on his disc. We have not attempted to give the details of structure in the equatorial region; but all the salient markings, both in magnitude and position, have been based on micrometer measurement.

March 5, 1886, shows the ring form of the great red spot, the small white spots south, which are seen at every opposition, the equatorial belt, and the fainter belts.

March 6, 1886, shows a large, oval white spot near the equator, three faint white spots south, the shadow of the third satellite, and the belt system.

May 2, 1886, shows the ring form of the great red spot, the small white spots south, the shadow of the second satellite, and the belt system.

May 7, 1886, shows the ring form of the great red spot, the small white spots south, the standard equatorial white spot, and the belt system.

The new star which appeared in the great nebula of Andromeda in August, 1885, was observed during the months of September, October, and November.

The following micrometrical measurements were made to determine its position with reference to the nucleus of the nebula:

NUCLEUS OF ANDR. NEB. AND NEW STAR.

Date.	P.	S.	Mag.	Eye-piece.
1885.692	256°.4	15″.23	7	II.
.701	256°.6	15″.88	8	III.
.703	255°.7	15″.98	8	V.
.706	254°.8	16″.25	8	II.
.720	256°.1	16″.46	8	V.
.758	255°.9	16″.15	8.5	II.
.772	254°.5	15″.28	8.5	V.
.870	255°.8	15″.67	9	III.
Mean:				
1885.740	255°.7	15″.86		

The partial eclipse of the moon on September 23, 1885, was observed by Prof. E. Colbert and myself. During the progress of the phenomenon a number of dry-plate photographs were taken with the equatorial, which show very satisfactorily the outline of the earth's shadow on the disc.

Miscellaneous observations have been made as follows:

Measures of known double stars.

Observations of the planet Saturn.

Examination of comets.

Photographs of the moon.

During the month of May, 1886, I secured two very fair negatives of the moon; one just before the first quarter, and the other a few days later. These negatives were made with a rapid emulsion plate and an exposure of two or three seconds.

The Observatory, as usual, has been open on Thursday evenings of each week to members of the Astronomical Society, and to classes in Astronomy from the city high-schools; and during the past two months numerous Chatauqua circles have been afforded the same privilege.

G. W. HOUGH,
Director.

CHICAGO, May 10, 1887.

APPENDIX A.

Motion of the Lunar Apsides.

E. COLBERT,
Formerly Superintendent Dearborn Observatory.

[The matter following on this and the seven succeeding pages was sent in proof, dated November 30, 1886, to Profs. C. A. Young, W. Harkness, and G. W. Hill. With some minor changes it was sent in pamphlet form to a few friends, over date of December 12, and then transferred to the February, 1887, number of the *Sidereal Messenger*. Three or four small errors in that issue are here corrected; and the author has added some explanatory statements, most of which have been given verbally or by note to parties who wished for further information in regard to some of the points in the paper.]

The *Principia* was published just two hundred years ago, and the motion of the line of apsides in the lunar orbit has been a vexed question with the mathematicians ever since. Newton tried to account for it on the gravitation theory, but left it with the remark, "*Apsis lunæ est duplo velocior circiter*" (the motion is about twice as great as this). Clairaut showed, in 1750, how to account theoretically for the other half, but the attempt to reduce the equations to a numerical form still left a residual, and when Laplace attacked the problem he was only able to make the theory responsible for 444 parts out of 445. It has been attempted to bridge over the difficulty by adding $2 \sin^2 \frac{1}{2}\gamma \,.\, d\Omega \div dt$ to the motion of the apsides; which in the case of the moon is practically equal to $4 \sin^4 \frac{1}{2}\gamma$, because $d\Omega \div d☽ \;=\; \frac{1}{2} \sin^2 \gamma; \;=\; 2 \sin^2 \frac{1}{2}\gamma$, nearly. It is evident from the subjoined reasoning that this quantity is not needed in that shape, neither is the existence of a second moon required to account for the perigeal motion.

If $1 - c$ represent the perigeal motion divided by that of the moon, then c^2 and $(1 - c^2)$ are the squares of two sides of the right-angled triangle the hypothenuse of which is unity; and $\sqrt{1 - c^2}$ is the perturbation of the radius vector. (This is not new.)

The quantity $1 - c^2$ comprises a radial, which involves r^3: a tangential, depending on the square of the velocity in the orbit, involving r^4; and one that originates in the displacement, being really a perturbation of the perturbation. The last is usually treated as a single quantity, namely as a function of r^4. It is more philosophical to regard it as furnishing a multiple for each of the other two instead of being a quantity simply additive. Also, for obtaining the mean motion of the apsides, it is sufficient to derive the constant portion of each function considered, being what we shall here call the "Average Value" of the quantity:

With g the mean anomaly, e the eccentricity, r the radius vector, and a the semi-axis major, we have the following extension of a well-known equation:

$$\begin{array}{l}
\frac{r}{a} = 1 + \frac{e^2}{2} \\
\left(-e + \frac{3}{8}e^3 - \frac{5}{3 \cdot 8^2}e^5 + \frac{7}{18 \cdot 8^3}e^7\right) \cos g \\
\qquad \left(-\frac{3}{8}e^3 + \frac{5 \cdot 3^2}{2 \cdot 8^2}e^5 - \frac{7 \cdot 3^4}{10 \cdot 8^3}e^7\right) \cos 3g \\
\qquad\qquad \left(-\frac{5^3}{6 \cdot 8^2}e^5 + \frac{7 \cdot 5^4}{18 \cdot 8^3}e^7\right) \cos 5g \\
\qquad\qquad\qquad \left(-\frac{7^5}{90 \cdot 8^3}e^7\right) \cos 7g \\
\left(-\frac{e^2}{2} + \frac{e^4}{3} - \frac{e^6}{16} + \frac{e^8}{180}\right) \cos 2g \\
\qquad \left(-\frac{e^4}{3} + \frac{2}{5}e^6 - \frac{56}{315}e^8\right) \cos 4g \\
\qquad\qquad \left(-\frac{27}{80}e^6 + \frac{81}{140}e^8\right) \cos 6g \\
\qquad\qquad\qquad -\frac{128}{315}e^8 \cos 8g
\end{array}$$

And an inversion of this series gives the following, which it is not necessary to carry out beyond the sixth power:

$$\begin{aligned}\frac{a}{r} = 1 &+ \left(+ e - \frac{e^3}{8} + \frac{e^5}{192}\right) \cos g \\ &\left(+ e^2 - \frac{e^4}{3} + \frac{e^6}{24}\right) \cos 2g \\ &\left(+ \frac{9}{8} e^3 - \frac{81}{128} e^5\right) \cos 3g \\ &\left(+ \frac{4}{3} e^4 - \frac{16}{15} e^6\right) \cos 4g \\ &+ \frac{625\, e^5}{16 \cdot 24} \cos 5g \\ &+ \frac{81\, e^6}{40} \cos 6g\end{aligned}$$

Raising each of these expressions to the required powers, and omitting all that is periodical, we have as "average values":—

For $\frac{r}{a}$: $1 + \frac{e^2}{2}$

" $\frac{r^2}{a^2}$: $1 + \frac{3}{2} e^2$

" $\frac{r^3}{a^3}$: $1 + 3 e^2 + \frac{3}{8} e^4$

" $\frac{r^4}{a^4}$: $1 + 5 e^2 + \frac{15}{8} e^4$

" $\frac{a}{r}$: 1

" $\frac{a^2}{r^2}$: $1 + \frac{e^2}{2} + \frac{3}{8} e^4 + \frac{5}{16} e^6$

" $\frac{a^3}{r^3}$: $1 + \frac{3}{2} e^2 + \frac{15}{8} e^4 + \frac{35}{16} e^3$

For the solution of the problem we take the following as the most probable values of the quantities named. They are deduced from the figures given by Newcomb, in 1879, in his paper on the recurrence of solar eclipses. The epoch chosen is A.D. 1800. The processes of the subsequent computation are given, as they may be of use in verification; and all of the logarithms have been computed closely enough to secure accuracy in the last figure of the result as here presented. The mark ' following some of the numbers or logarithms indicates that the next succeeding figure would be nearly 5. The same mark inverted, thus, ˌ shows that the given value is too great by half a unit, or nearly so, in the right hand place:

		Logarithms.
☉'s daily motion,	3548″.1927904	3·55000 72091
Sidereal year, days,	365 ·2563647	2·56259 77924
☽'s synodical rev. days,	29 ·53058844	1·47027 21009'
Sidereal rev. days,	27 ·32166120	1·43650 71016
☽'s daily motion,	47434″.890233	4·67609 78999'
☽'s — ☉'s daily motion,	43886″.697443	4·64233 29006
☽'s π, daily motion,	400″.9187565	2·60305 63747
Half square ratio sidereal periods;		
	= (1 ÷ 357·447).	97·44678 86227 2
	358·447 ÷ 357·447	0·00121 32942 7
Nominal perturbation; $\frac{m}{2}$	= 0·00278 98145	97·44557 53284 5

Then for $e_{,}$, the eccentricity of the earth's orbit, with $e_{,}$ = 0·01679228, we have by a preceding formula:

$(a_{,} \div r_{,})^3$	= 1·00042 31201 4	0·00018 37198 8

and taking an approximate value for ☽'s e, with γ = about 5° 8′ 40″.6 we obtain E, the perturbation of the perigeal motion due to the earth's elliptical figure, as follows:

Constant of precession (JULIAN) =	54″.94625		1·73993 805
Obliquity, (1800) = 28° 27′ 54″.8		cos	9·96251 23'
	50″.40230		1·70245 04
Daily soli-lunar	0″.1379940		9·13986 02
☽'s $m \div a^3$ × ☉'s $a_{,}^3 \div m_{,}$			0·33673 10
☽'s $(a \div r)^3$	1·00453 806		0·00196 64
$1 - (3 \div 2) \sin^2 \gamma$			9·99473 02ˌ
	2·154902		0·33342 75
☉'s $(a_{,} \div r_{,})^3$	1·000423		
Sum of ☽ and ☉ =	3·155325		0·49904 41
(3 ÷ 2) seconds sidereal arc in solar day,			6·28988 37
(Solar days in sidereal year)^2		a. c.	94·87480 44
Obliquity of ecliptic,		cos	99·96251 23'
Daily soli-lunar precession,	0″.13799 40	a. c.	0·86013 98
	306·468		2·48638 44

Twice do × Moon's mass, = 7·51744 a. c. 99·12395 63
Lunar precession, 0″.09424 18 98·97424 36
E on perigee, 0″.01253 718 98·09819 99
= d ☽ (0·00000 02643 03); 93·42210 20
$1 + \big(2E \div (1 - c^2)\big)$ = 1·00003 14038 5 = 0·00001 36383

Our value of E is slightly larger than the one given by LAPLACE. The precession here used is greater than that observed; the difference being due to a planetary perturbation which causes the equinox to move forward a little more than 17″ in a century. The number 306·468 is the earth's moment of inertia divided by the momentum of the ring of matter that forms our equatorial protuberance.

The value of e is, however, a direct function of the perturbation. We obtain it as follows:

$(1 - c^2) \div 6$ 97·44799 80074
Syn. ÷ sid. period of ☽ 0·03376 49993'
= $(e^2 \div p^2)$ 97·48176 30067'

Whence e = 0·05489 97758 98·73957 057
e^2 = ·00301 39854▴ 97·47914 11392
p = 0·99698 60146 9·99868 90662

Then, for the averages on radius vector we have:

$(r \div a)^3$ = 1·00904 53626 4▴ 0·00391 06908 2▴
$(r \div a)^4$ = 1·01508 69595 3 0·00650 32485 8

Also for the inclination we have:

$$\left.\begin{array}{ll} 8\,e^2 \div 3 & = 0{\cdot}00803\;72943\;1 \\ 3\,e^4\,p \div 8 & = +\qquad 33962\;7 \end{array}\right\}; \quad \gamma = 5^\circ\, 8'\, 39''815 + 0''804$$

$\sin^2 \gamma$ = 0·00804 06905 8 97·90529 335

When n is an even power, the average value of $\sin^n$ is

$$\frac{n\,(n-1)\,.\,(n-2)\,\ldots\,(\tfrac{1}{2}n+1)}{2^n\,(1\,.\,2\,.\,3\,.\,4\,\ldots\ldots\,\tfrac{1}{2}n)}$$

Giving $(1 \div 2)$ for $\sin^2$; $(3 \div 8)$ for $\sin^4$;
$(5 \div 16)$ for $\sin^6$; $(35 \div 128)$ for $\sin^8$; etc.

Cos² ☽'s latitude = $1 - \sin^2\gamma \sin^2$ longitude. Hence we get the following values, not for the latitude at any particular point but the *average* cos, cos², etc., of the ☽'s latitude:

$$\cos \text{ lat.} = 1 - \frac{1}{4}\sin^2\gamma - \frac{3}{64}\sin^4\gamma - \frac{5}{256}\sin^6\gamma - \frac{175}{16384}\sin^8\gamma.$$

$$\cos^2 \text{lat.} = 1 - \tfrac{1}{2}\sin^2\gamma.$$

$$\cos^3 \text{lat.} = 1 - \frac{3}{4} \sin^2 \gamma + \frac{9}{64} \sin^4 \gamma + \frac{5}{256} \sin^6 \gamma + \frac{105}{16384} \sin^8 \gamma.$$

$$\cos^4 \text{lat.} = 1 - \sin^2 \gamma + \tfrac{3}{8} \sin^4 \gamma.$$

These relations give us:

$\cos^3$ lat. $=$ 0·99397 85840 3 : 9·99737 70273 2

$\cos^4$ lat. $=$ 0·99198 35541 7 : 9·99650 44721 6

And these multiplied into the average values of r^3 and r^4 give the average third and fourth powers of the projection of r on the plane of the ecliptic:

It is important to note that the sum of the cube cosines for an inclination of 5° 8′ 40″.619 is equal to that for a medial value of 0″.804 less; so that our computation gives us 5° 8′ 39″.815 ± 5′. This corresponds precisely to the Hansenian value of 5° 8′ 39″.96 corrected by the — 0″.15 deduced by Newcomb from a discussion of the Greenwich and Washington observations from 1862 to 1874.

If ξ be the ☽'s distance divided by that of ☉, and taking the parallaxes as equal to 3422″.75 and 8″.794, we have $\xi^2 = 0{\cdot}000006601803$; and the value of $3\,m \div 2$ must be multiplied into $(1 + \frac{9}{8}\,\xi^2$, etc.) and $(1 + \frac{15}{8}\,\xi^2$, etc.) for the perturbative series in the direction of r and perpendicular thereto.

For the effect due to the "variation," let $1 + x$ and $1 - x$ represent the semi-axes of the ellipse, the longer axis being in quadratures and the other in the syzigies. Let w be the *mean* angular distance from the direction of the minor-axis of this ellipse. Then if $r_\circ$ denote the distance from the centre to any point in the circumference, we have, by comparison of the ellipse with its circumscribing circle:

$$r_\circ^2 = \sin^2 (w + dw) \,.\, (1 + x)^2 + \cos^2 (w + dw) \,.\, (1 - x)^2;$$
$$= 1 + x^2 - 2x \cos 2w + 4\,\text{Q}\; x^2 \sin\; 2w;$$

if $\text{Q}x$ denote the maximum perturbation in longitude in the average orbit:—that which gives unequal areas in equal times.

Now, $1 + x^2 = a_\circ^2$, if $a_\circ$ be the radius of the circle of equal area that would have been described in the absence of compression; because $(1 + x) \,.\, (1 - x) = 1 - x^2$. Hence

$$r_\circ^2 = a_\circ^2 - 2x \cos 2w + 4\,\text{Q}x^2 \sin^2 2w,$$

if there were no change of area; and becomes

$$\frac{x^2}{3} + (1 - 2x \cos 2w + 4\,\text{Q}x^2 \sin^2 2w)$$

on account of solar perturbation on $a_\circ$. From this we have:

$$r_\circ^3 = \frac{x^2}{2} + \left(1 + \frac{3}{4}x^2 + 3\,\mathrm{Q}x^2 + \frac{9}{4}\mathrm{Q}^2x^4\right)$$

$$r_\circ^4 = \frac{2}{3}x^2 + \left(1 + 2x^2 + 4\,\mathrm{Q}x^2 + 6\,\mathrm{Q}^2x^4\right).$$

The numerical values are as follows:

$3\,(t \div t_,)^2$		a. c.	1·77506 01269'
e^2			97·47914 11392
$(\text{syn} \div \text{sid})^2 - 1$	=	0·16823 44223	9·22591 48612
$= \quad 4x \div (1+x)^2$			98·48011 61274

which is the square of the average eccentricity in the hypothetical orbit described by the moon once in each synodical lunation.

x =	·00766 81608		97·88469 12105
$1 + x$			0·00331 75364
$1 - x$			9·99665 69260
x^2	·00005 88006 9		95·76938 24210
$(1+x) \div (1-x)$ =	tan (45° + 1581″.633)	=	0·00666 06104
$1 + (x^2 \div 2)$			0·00001 27682
$(1 - c^2) \div 2$			97·92511 926
☽'s daily motion ÷ p average $\cos^3$ lat.			4·68003 181
	402″.857	=	2·60515 107
add	1581″.633		
	1984″.490		3·29764 88
	Syn ÷ sid ☽		0·03376 50
	2144″.934; = Variation;	=	3·33141 39
And Q =		(log)	9·40603 472'

Taking the logarithms, we have:

	For r^3	For r^4
Function of e	0·00391 06908 2	0·00650 32485 8
" γ	9·99737 70273 2	9·99650 44721 6
" x	0·00005 14311 3	0·00009 41058 1
" ξ	0·00000 32255 0	53758 1
(logs.)	0·00134 23747 6'	0·00310 72023 6

and the numbers are } 1·00309 57139 8
1·00718 02531 3
2·01027 59671 1

The logarithm of the sum	=		0·30325 56806 9
$(3 \div 2)\, m$			97·92269 65831 7
Solar; $(a_{,} \div r_{,})^3$,			0·00018 37198 8
Earth perturbation,			0·00001 36383
Planetary perturbation,			9·99999 96358
$1 - c^2$		·01683 25246	98·22614 92578
$1 - c$		·00845 19803	97·92695 84751 5
☽			4·67609 78999 5
$(1 - c)$	=	400″.91875 69	2·60305 63751

(The planetary perturbation is that adopted by Hill in his tables of Venus. It is what Laplace terms the "indirect" perturbation; being that due to the enlargement of the earth's radius vector by planetary action, which lessens the solar disturbing force. The direct planetary perturbation is neglected, being infinitessimal as between the earth and moon.)

This result is identical with the value of the perigeal motion which Newcomb has obtained from a discussion of the eclipses of 2500 years preceding the present century. The difference between the two is less than one part in 1,000,000,000. Hence the problem is completely solved.

The following is the resulting value of the daily motion of g, the mean anomaly: 47033″.97147 6

If any one should object to our deduction of the values of e and γ from that of the quantity sought he is respectfully referred to the top of page 174 of Loomis' Practical Astronomy, with the fact that a comparison of the rates of change in the values of the quantities shows this to be a parallel case with that given by Loomis on page 173. It is not necessary to our result to carry out the logarithm of e^2 to ten places; but I think there needs be no doubt in the future in regard to the precise values of e, γ, or x in the lunar orbit. Of course the numerical values of these quantities are slightly reduced since the beginning of the century by the decreasing eccentricity of the earth's orbit.

Chicago, December 12, 1886.

EXPLANATORY.

The quantity $\sqrt{1 - c^2}$ is the perturbation in terms of the moon's mean motion, not of her radius vector.

It is a fundamental principle in celestial mechanics that motion in the theoretically undisturbed orbit is a function of a, the semi axis major of that orbit, but that the disturbing force is a function of the varying ratio of the radii vectores in the orbits of the disturbed and disturbing masses. Hence the expressions in the lower part of page 17;—which are the same as would be obtained by dividing the orbit into a very large number of equal areas, and then taking the sum divided by the number of all the resulting radial values, as stated.

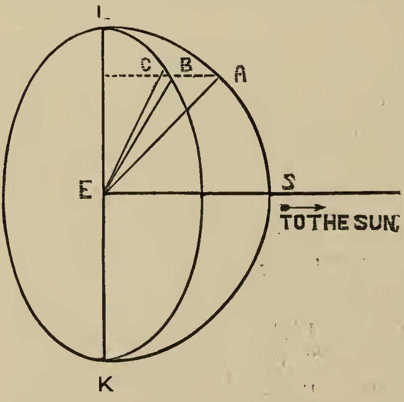
If β denote the moon's latitude, and ρ the projection of her radius vector on the plane of the ecliptic, then $\rho = r \cos \beta$; $\rho^2 = r^2 \cos^2 \beta$; etc. The quantities given in lines 4 and 5 on page 20 are the average values of ρ^3 and ρ^4; being what would be obtained by adding into one sum the cubes, and into another the fourth powers, of all the projections of the radius vector in the orbit divided as above noted, and dividing by their number. The results are multipliers for force in the line of the ecliptic, which is the average of all the paths described by the moon among the stars in the course of one period of a little more than eighteen years.

The quantity $1 - c^2$ is the sum of three measures of force: 1, that of the sun, which is positive in some positions and negative in others; but the sum in every lunation is positive, increasing the value of the moon's radius vector. 2, that of the earth's equatorial protuberance, which acts the same as would a ring of matter outside the earth. 3, the other planets of the solar system, the sum of their attraction increasing the distance between the earth and the sun, thus lessening his disturbing force.

The quantity denoted by m (line 15, page 18) is the relative mass of the sun divided by the cube of his relative distance, that of the earth and moon being taken as unity in each case. Hence m would equal the square of the ratio of the times of sidereal revolution but for the fact that the observed lunar period is already affected by the solar disturbing force. The necessity for a reduction of value, as given, was first pointed out by Dr. MASKELYNE. The square of the moon's velocity in her relative orbit is equal to a constant multiplied into $(a \div r)^2$, plus $3\, m\, r^2 \sin^2 w \div a^2$. By the principle deduced on page 19 (line 7 from bottom), this would have an average value of, Constant plus $(3\, m \div 2)$ but for the existence of another inequality;—The distance between the centers of sun and moon being represented by λ we may express the value of $(1 \div \lambda)^3$ in terms of $(1 \div a_{,})^3$ and obtain the two series, all the required terms of which are given in line 18 of page 20.

The relative path of the moon around the earth may be represented by a dual orbit. The first and least eccentric is the one usually referred to in the text books. Its major axis revolves once while the moon revolves about a hundred and twenty times. The greatest and least distances are $a\,(1 + e)$ and $a\,(1 - e)$. The semi parameter, denoted by p, is equal to $a\,(1 - e^2)$. The second, having an eccentricity nearly equal to $(19\,e \div 6)$, revolves once in each ~~synodical lunation~~, having its minor axis always directed toward the sun. The first has the earth in one focus, the second has the earth in the center, E.

For the second ellipse. The sun is in the prolongation of the line $E\,S$. If in the circumscribing semicircle, $K\,S\,A\,L$, we draw $A\,C$ parallel to $S\,E$, the angle $S\,E\,B$ is the angular distance from the sun in the ellipse, corresponding to the mean angular distance $S\,E\,A$, which we have denoted by w. The angle $A\,E\,B$ would be the apparent displacement, or difference between the mean place and the true, if equal areas were described in equal times. But the solar perturbation causes the actual velocity to be greater in syzigies than in quadratures, the result of which is a perturbation of area, represented by the angle $B\,E\,C$. The sum of these, or the angle $A\,E\,C$, is the "Variation," which



varies nearly as sin. 2 w. The actual radius vector, EC, is evidently greater than EB.

The eccentricity in each of these ellipses varies with the changing relative distances of the earth and sun from the moon. But that of the first is subject to a change peculiar to itself, depending on the angular distance of the perigee from the place of the sun. Its eccentricity is nearly one-fifth greater than the mean when the line of apsides is in syzigies, and nearly one-fifth less than the mean value when the apsidal line is in quadratures. Also the angular velocity of the apsidal line itself is variable, and is even retrograde during a part of the lunation. But the sum of all the plus and minus deviations from the average values of the quantities as derived in our paper, is equal to zero.

The solar force on the moon is greater than the earth force on the moon. Hence the well-known fact that the actual path of the moon is always concave toward the sun. From this it follows that the eccentricity of the lunar orbit around the earth, as distinguished from the orbit which it describes in common with the earth, is *entirely* due to the disturbing force. And the whole of this eccentricity is due to the current action of the sun, except that very small part which we have neglected as infinitessimal within the limits of observation, The same is true of the theoretical ellipse described once in each synodical lunation. There is no more reason for independent eccentricity in one of these ellipses than in the other.

The solar force which causes the existence of e and measures its value, causes also an augmentation in the value of a in the lunar orbit. The same force in the second orbit causes an enlargment of the value of $a_{\circ}$, as stated in last line of page 20, which decreases the average parallax by only about the thirtieth part of a second. The larger part of the corrections given as functions of x, on page 7, is due to the expression derived in line 28 of page 20.

Regarding the corrections for λ or ξ as included in the value of m, and those for x as included in r, we have the following as the component parts of $1 - c^2$ which are due to the solar force:

$$\frac{3\,m}{2}\int \frac{r^3}{a^3} \cos^3 \beta \, \frac{a_{\prime}^{3}}{r_{\prime}^{3}} + \frac{3\,m}{2}\int \frac{r^4}{a^4} \cos^4 \beta \, \frac{a_{\prime}^{3}}{r_{\prime}^{3}}\,;$$

the first being radial and the second tangential. Neglecting the square and higher powers of e, the first part of this expression gives $\sqrt{1 - c^2} = 3\,m \div 4$, which is the first approximation arrived at in "the good old way" of reasoning about it. Dividing this by $(1 - \frac{1}{2}\,m)$, for diminution of square of velocity in the orbit, gives $(3\,m \div 4) + (3\,m^2 \div 8)$, which is where the process stopped previous to the investigation of CLAIRAUT, who added terms in m^2, which give a value of about $27\,m \div 20$.

The mean disturbing force of the sun (page 22, line 2), increased by the ellipticity of the earth's orbit, and diminished by planetary action, is equal to 0·0083730, very nearly. And *this is the whole of the mean force.* Hence its square and higher powers do not enter into the development, except artificially in compensation for a defect in the other part of the process. That other part, so far as the solar perturbation is concerned, can logically consist only of terms depending on the magnitude and position of r;—that is, on functions of the moon's angular distances from her perigee and node, and from the sun. The average effective value of her radius vector is increased by the first and last of these, and diminished by the second, from what it would be if her orbit could be circular and in the plane of the ecliptic. This is the logic of the method developed in the preceding pages. It is so novel that some may deem it unsound, but is nevertheless offered as the only true way of attacking this hitherto difficult problem. The complete elimination of the residuals which have taxed the brains of mathematicians for the last two centuries forms no small reason why it should be closely and candidly examined by the few who are competent to pass judgment upon it intelligently.

APPENDIX B.

CATALOGUE OF 209 NEW DOUBLE STARS.

Discovered with the 18½-inch Refractor of the Dearborn Observatory, Chicago, U.S.A., by Prof. G. W. Hough, Director.

The double stars in the following list, with the exception of a few of the least interesting pairs, are for the most part difficult objects, requiring good atmospheric conditions for their measurement with the Chicago telescope.

The following is a synopsis of our catalogue according to distance:

Distance.	No. of Pairs.
0″ to 0″.5 - -	25
0″.5 to 1″ -	25
1″ to 2″ - -	43
2″ to 5″ -	77
Over 5″ - -	39
Total,	209

The pairs having a greater distance than 5″, with a few exceptions, are excessively unequal in magnitude.

In the table of observations, the first column is the number; second, authority for place; third and fourth, right ascension and declination; fifth and sixth, position angle and distance; seventh, magnitudes; eighth, epoch of measures.

The sign ± indicates an estimation only. In the case of very close pairs, however, when the distance is given ± 0″.3, it may be regarded as the maximum.

I am indebted to Mr. S. W. Burnham for the loan of star catalogues, and also for making a comparison of my list with his general catalogue (manuscript), and checking off all pairs which were not new.

Abbreviations used in the catalogue:

D.M.	denotes	Durchmusterung.
Glasg.	"	Glasgow Catalogue of 6415 Stars.
Rog.	"	Harvard Observatory, Vol. XV, Part 1, Catalogue of 1213 Stars.
L.	"	Lalande.
A. G. L.	"	Leiden Annalen, Vierter Band.
A. O. E.	"	Argelander-Oeltzen.
Rad.	"	Radcliffe.
Schj.	"	Schjellerup.
W.	"	Weisse.
Σ	"	F. G. W. Struve.
O Σ	"	Otto Struve.
β	"	S. W. Burnham.
H.	"	Herschel.

This catalogue has been published in full with individual measures in the "Astronomische Nachrichten," Vol. 116, Nos. 2778-9.

CATALOGUE OF 209 NEW DOUBLE STARS.

No.	Catalogue.	R. A. 1880.	Decl. 1880.	Pos.	Dist.	Mags.		Epoch.
		h m s	° ′	°	″			
1	W_2 $0^h.75$	0 05 15	+28 56	348·6	1·00	8·5	8·5	84·396
2	D.M. 34°.72 ..	0 25 42	+34 58	100·5	2·20	9·5	12·5	81·801
3	W_2 $0^h.656$ ...	0 27 03	+39 27	121·2	0·50	7·7	10	85·808
4	D.M. 33°.114 .	0 44 10	+33 18	202·0	1·48	9	9	82·833
5	A.G.L. 139·50	0 59 18	+32 21	310· ±	0·4 ±	8	8	85·929
6	W_2 $1^h.119$ ...	1 08 37	+37 51	111·3	1·29	8	11	81·843
7	W_2 $1^h.406$ ...	1 20 26	+40 29	158·9	13·47	6	13	85·841
8		1 21 23	+34 04	246·0	3·26	9·7	10·3	83·183
9	D.M. 20°.228 .	1 22 34	+21 06	92·8	2·77	9	10	83·922
10	W_2 $1^h.1176$ ..	1 51 43	+37 06	198·5	2·50	8	12	84·562
11	D.M. 33°.333 .	1 52 24	+33 38	139·7	4·59	9	9·4	84·253
12	W_2 $1^h.1292$ ..	1 55 42	+34 05	100·4	3·10	8	10·7	83·913
13	L. 5498......	2 52 45	+26 49	163·7	1·82	7	12	83·192
14	W_2 $3^h.506$ ...	3 25 57	+27 52	21·1	1·82	8·2	8·7	83·502
15	W_2 $4^h.320$ ...	4 16 54	+29 51	147·2	0·81	8	8	82·128
16	A.G.L. 155·52	4 49 16	+34 02	28·5	0·6 ±	8·5	11	85·914
17	W_2 $4^h.1122$ ..	4 51 39	+30 50	52·2	4·38	8	10	82·142
18	L. 9876......	5 11 28	+33 52	164·1	3·94	7·7	13	83·505
19	L. 10871.....	5 39 55	+35 07	342·2	7·02	6·5	12·5	86·200
20	W_1 $5^h.1182$ ..	5 48 06	+14 12					
	A and B....			276·8	7·82	7	12	86·191
	A and C....			287·3	50·21		11·5	86·197
21	L. 11326.....	5 53 28	+27 34	238·4	9·81	6·7	13	84·705
22	W_1 $6^h.127$ ...	6 06 50	+10 17	195·1	0·63	8	8	86·180
23	W_1 $6^h.149$ ...	6 07 25	+14 29	248·6	2·76	8·2	12	84·720
24	W_1 $6^h.277$ ...	6 11 30	+ 9 22	156·0	4·60	8	11·5	84·689
25	D.M. 25.°1238	6 14 57	+25 17					
	A and B....			236·2	0·3 ±	9	9	86·219
	A and C....			45·1	32·84		12·5	83·266
26	W_2 $6^h.1319$ ..	6 44 44	+20 28	200·8	5·06	8·5	12	82·745
27	D.M. 20°.1633	6 48 58	+20 15					
	A and B....			126·2	3·01	9	9	82·231
	A and C....			165.0	35·		9	
28		6 50 00	+27 08	256·8	5·37	9·5	9·5	86·222
29	D.M. 20°.1694	6 58 06	+20 11	158·5	3·43	9·5	9·7	83·318

3. A close and difficult pair.

5. A close and difficult pair, 7·5 mag. star precedes 1^m 13^s and 12′ north.

6. Σ 104 follows 1^m 30^s and 2′ south.

7. A rather difficult pair, owing to the faintness of the companion.

9. 7 mag. star in the field 7s preceding and 0′.6 north.

16. A close and very difficult pair, owing to the great inequality of the components.

18. A very difficult pair, owing to the faintness of the companion.

21. A difficult pair, owing to the faintness of the companion.

23. Σ 877 follows 30^s and 8′ north.

25. A close and difficult pair.

No.	Catalogue.	R. A. 1880.	Decl. 1880.	Pos.	Dist.	Mags.		Epoch.
		h m s	° ′	°	″			
30	D.M. 29°.1475	7 04 46	+29 53	125·9	5·48	9	9	86·241
31	D.M. 30°.1454	7 06 20	+30 09	7·4	10·91	9	9·5	86·249
32	D.M. 30°.1456	7 06 41	+30 17	162·2	4·59	9	9	86·249
33	W^2 7^h.338 …	7 12 51	+22 23	n. p.	3·±	9	12	83·214
34	D.M. 21°.1620	7 24 08	+21 20	13·±	2·5±	9·5	9·5	83·246
35	D.M. −0°.1768	7 31 24	− 0 44	222·3	0·88	8	9	82·233
36	D.M. 25°.1763	7 40 14	+25 45	299·9	0·98	8·5	8·5	83·195
37		7 43	− 2 00	177·3	1·50	8	8	82·233
38	W^2 8^h.81 ….	8 06 33	+28 08	80·5	7·47	8	13	86·222
39	D.M. 27°.1580	8 10 59	+27 46	348·2	6·17	9	10	83·285
40	A.G.L. 18·47.	8 43 41	+31 51	272·3	0·55	9	9·3	84·742
41	D.M. −1°.2192	8 57 33	− 1 55	69·8	4·01	9	10	82·804
42	D.M. 34°.1961	9 06 49	+34 03	6·1	1·38	9·5	9·5	85·768
43	W^2 9^h.203 …	9 11 47	+21 19	314·4	0·37	8	8·5	85·759
44		10 05	− 5 35	10·9	0·41	8	8	84·324
45	D.M. 6°.2280 .	10 09 49	+ 6 35	145·2	9·60	9	10	84·352
46		10 53 40	+36 45	97·2	2·01	10	10	85·334
47	L. 21171…..	10 56 18	+36 19					
	A and B C..			286·4	120·05	7	9	83·367
	B and C….			140·3	0·62	9	9	84·360
48	W_2 10^h.1130..	10 57 31	+23 48	6·7	1·66	8	11·2	82·740
49	A.O.E. 11384.	10 57 36	+57 38	357·1	7·20	8	11·2	83·863
50	W^2 11^h.94 …	11 07 02	+41 44	31·2	3·10	7	10	82·355
51	Schj. 4146….	11 25 29	+ 8 32	173·6	2·71	7	12	82·262
52	11 Comac…..	12 14 39	+18 27	43·5	9·08	5	13	83·658
53	L. 23196 …..	12 17 29	+14 35	295·3	1·89	8	11·7	82·946
54	W_2 12^h.573 ..	12 35 46	+10 33					
	A and B C..			102·9	120·11	7	10	82·430
	B and C ….			151·0	1·48	10	10	82·431
	B C and D..			35·7	2·±		13·5	83·411
55	L. 24574 …..	13 08 01	+30 27	180·±	0·6±	7	11	84·406
56	L. 25605 …..	13 48 21	+42 47	131·1	6·74	6·7	13	83·441
57	L. 26079 …..	14 07 21	+42 59	206·8	1·83	8	13	83·490
58	W_2 14^h.162 ..	14 08 56	+41 45	226·5	8·82	7·5	11·7	84·115

36. Measured 1887·241, p. = 285°.1, dist. = 0″.4± ; very difficult. There appears to have been rapid change in the distance.

38. A difficult pair, owing to the faintness of the companion. There is a 12 mag. star s. p. 25″.

40. A very delicate pair, not difficult.

41. There is a 12·5 mag. star, p. = 232° and d. = 29″.

43. A close and difficult pair.

44. A close and difficult pair. Approximate place.

46. 6 mag. star precedes 50^s and 1′ north.

50. In D.M. the magnitude is 6·2.

52. This is an interesting pair, but very difficult to measure, owing to the minuteness of the companion.

53. A rather difficult pair.

56. A rather difficult pair, owing to the faintness of the companion.

57. A difficult pair, very unequal.

No.	Catalogue.	R. A. 1880.	Decl. 1880.	Pos.	Dist.	Mags.		Epoch.
		h m s	° ′	°	″			
59	D.M. 45°.2209	14 37 06	+44 54	6·6	6·90	8	12·5	86·493
60	L. 27803	15 08 50	+35 20	38·3	0·38	7·5	7·6	85·040
61	W_2 $15^h.274$ . .	15 13 25	+35 33	253·3	1·96	8·2	13	86·565
62	W_2 $15^h.314$ . .	15 16 05	+35 25	283·2	1·02	8·7	8·7	86·565
63	D.M. 28°.2446	15 30 46	+28 47	301·1	1·04	9	9·2	85·574
64	D.M. 28°.2578	16 25 58	+28 00	109·7	4·45	9·7	9·7	84·005
65	L. 30761	16 48 12	+22 53	153·0	1·90	8	13	86·520
66	D.M. 32°.2839	16 58 46	+32 47	246·3	13·84	8·5	13	86·624
67	D.M. 35°.2947	17 13 23	+35 44	261·5	6·30	8·5	12·5	84·605
68		17 25	+63 18	258·1	1·45	10	10	82·500
69	W_2 $17^h.1054$.	17 33 56	+37 00	141·0	1·64	8·3	12·1	82·856
70	W_2 $17^h.1299$.	17 41 02	+30 35	110·1	0·46	8·1	8·1	83·019
71		17 48 48	+55 24	226·8	3·67	9·2	9·6	85·134
72	D.M. 33°.2990	17 51 27	+33 27	7·8	3·22	9	11·5	85·110
73		17 53	+35 42					
	A and B. . . .			30·5	1·68	9	9	85·105
	A B and C. .			301·9	8·38		13	85·105
74	D.M. 33°.3000	17 54 00	+33 30	122·2	3·01	8·7	12·7	83·635
75	W_2 $17^h.1727$.	17 54 45	+34 05	212·7	1·29	9	11	83·645
76	L. 33130	17 57 12	+33 20	202·4	13·34	6	13	84·754
77	L. 33163	17 57 49	+40 20	312·0	1·87	7·7	12	84·200
78	W_2 $17^h.1917$.	18 00 29	+33 16	202·3	7·74	7	13	84·811
79	D.M. 33°.3025	18 01 47	+33 25	7·5	0·37	9	9	84·605
80	A.G.L. 91·7. .	18 04 47	+35 09	188·4	0·46	7·5	11	84·721
81	W_2 $18^h.140$. . .	18 05 58	+32 20	211·3	2·53	8	11·7	83·639
82	L. 33521	18 07 22	+33 25	207·1	0·55	6	10	85·113
83	W_2 $18^h.502$ . .	18 18 34	+27 28	262·3	0·3±	9	9	84·788
84	D.M. 27°.3012	18 19 28	+27 22	312·9	2·02	9	11	85·698
85	W_2 $18^h.561$ . .	18 20 37	+28 01	196·2	4·70	8	12	85·066

60. A close and difficult pair. 7·5 mag. star follows 35^s and 2′ north.

61. A difficult pair, owing to the closeness and inequality of the components. 8 mag. star precedes 30^s and 2′ north.

63. 7 mag. star follows 14^s and 2′ north.

65. A difficult pair. 8 mag. star same R.A. and 4′ north.

66. A difficult pair. The north star of a group of three.

69. An unequal and rather difficult pair.

70. A close and difficult pair. 8 mag. star precedes 15^s and 1′ north.

73. 7 mag. star in the field, following 10^s and the same declination.

76. A rather difficult pair, owing to the faintness of the companion.

77. A very difficult pair. Σ 2267 south 8′ and the same R.A.

78. A difficult pair, owing to the faintness of the companion.

79. A close and difficult pair.

80. A close and very difficult pair.

82. A very difficult pair, owing to the closeness and inequality of the components.

83. A close and difficult pair. 7·5 mag. star in the field south. Σ 2315 follows 1^m 38^s and 7′ south.

84. Σ 2315 follows 45^s and 2′ south.

No.	Catalogue.	R. A. 1880.	Decl. 1880.	Pos.	Dist.	Mags.		Epoch.
		h m s	° ′	°	″			
86	A.G.L. 91·35.	18 29 14	+35 05	181·7	0·37	8	8·3	86·744
87	W_2 $18^h.960$ . .	18 33 15	+16 26	258·7	0·28	8	8	83·689
88		18 39	− 9 40	208·1	2·03	9	9	85·567
89	W_2 $18^h.1481$.	18 49 13	+37 19	166·6	6·01	8	12	86·226
90	W_2 $18^h.1527$.	18 50 18	+37 10	225·4	3·76	8	12	85·196
91	Rog. 866	18 52 54	+17 12	132·5	6·27	6	11·7	86·724
92	D.M. 32°.3295	18 56 21	+32 21	41·9	1·06	9	9·1	86·185
93	Schj. 7117. . . .	18 56 36	+14 16	334·6	1·07	7·7	12	83·682
94		18 57	−11 30	314·7	6·97	9	11·5	85·150
95	D.M. 27°.3241	19 00 49	+27 06	218·8	0·38	8	8	85·790
96		19 01	−12 55	133·7	2·85	9	10·7	86·781
97	W_2 $18^h.1920$.	19 01 52	+31 33					
	A and B. . . .			19·1	0·73	9	9	81·956
	A B and C. .			57·6	15·36		13	81·646
	A B and D. .			312·0	38·		12·5	81·645
98	L. 35917	19 03 25	+26 54	163·6	0·27	8	8	86·412
99	W_2 $19^h.51$ . . .	19 03 30	+30 20	128·0	0·03	9	9	81·961
100	W_2 $19^h.29$ . . .	19 04 09	−12 20	327·5	4·80	8	11	84·638
101	D.M. 30°.3471	19 08 38	+30 48	113·0	1·89	9·3	10	81·891
102	W_2 $19^h.338$ . .	19 12 13	+32 55					
	A and B C . .			345·0	86·10	7	10	84·818
	B and C			236·6	1·89	10	10	84·819
103		19 12 33	− 3 40	248·4	2·59	9·2	9·2	85·187
104		19 15 38	− 7 50	125·4	4·91	8	12·2	85·135
105	W_2 $19^h.462$ . .	19 16 49	+16 26	188·4	2·59	8·5	10	83·690
106		19 21 53	− 3 16	214·5	1·08	9	11	83·765
107	W_1 $19^h.652$ . .	19 27 26	− 0 32	106·2	6·21	8	11·5	86·786
108	L. 37108	19 28 47	+33 13	45·9	0·43	8	8	85·213
109	A.O.E. 19844.	19 33 06	−15 07	115·0	10·92	7	13	83·659
110	D.M. 18°.4174	19 33 35	+18 25	76·8	2·04	9·5	9·5	86·217
111	L. 37409	19 35 14	+33 42	0·8	0·77	6·5	11	85·190
112	D.M. 18°.4197	19 36 09	+18 21	80·8	2·64	9	9	85·613

86. A close and very difficult pair. 8·3 mag. star follows 45^s and 1′.5 south.

87. A very close and difficult pair. D.M. 7·5 mag. 8 mag. star precedes 28^s and 2′ south.

90. β 137 precedes 30^s and 4′ north.

92. β 649 precedes 1^m 57^s and 3′ south.

93. A difficult pair, owing to the inequality of the components.

95. A close pair. 8 mag. star precedes 2^s and 7′ north.

98. A very close and difficult pair. 8·5 mag. star follows 18^s and 6′ north.

99. A very close and difficult pair. Σ 2465 precedes 21^s and 9′ north.

103. Σ 2490 precedes 51^s and 1′ south.

106. Approximate place; ε aquilæ follows 2^m 30^s and 14′ north.

108. A close and rather difficult pair.

109. A difficult pair, owing to the faintness of the companion.

111. A very difficult pair, owing to the closeness and inequality of the components.

No.	Catalogue.	R. A. 1880.	Decl. 1880.	Pos.	Dist.	Mags.		Epoch.
		h m s	° ′	°	″			
113		19 37 44	– 16 24	14·4	3·67	9·5	11	84·705
114	AC. = S. 726. .	19 41 59	+ 32 36					
	A and B. . . .			238·6	3·12	6·5	13	86·256
	A and C. . . .			201·5	31·67		8	85·838
115	W$_2$ 19^h.1576 .	19 49 28	+ 16 56	326·0	4·96	8·1	13	86·702
116	L. 38019	19 50 38	+ 17 36					
	A and B. . . .			22·2	3·90	8	12·7	86·711
	A and C = H. 2908			9·6	17·85		13	86·714
117		19 57 56	+ 33 21	313·5	5·08	9·1	10·4	83·477
118	D. M. 33°.3701	19 58 07	+ 33 20	27·1	2·85	9·1	11	83·477
119	W$_2$ 20^h.37 . . .	20 04 27	– 13 13	199·7	3·29	8·7	8·7	83·680
120	D. M. 34°.3907	20 07 22	+ 34 14	113·8	1·01	9	11·5	82·688
121	W$_2$ 20^h.243 . .	20 07 25	+ 34 07	17·8	21·43	7	12·5	84·715
122	D. M. 28°.3677	20 09 56	+ 28 18	72·5	1·07	9	9·7	86·241
123		20 11 12	– 16 05	215·3	2·70	9	9	85·229
124	W$_2$ 20^h.514 . .	20 14 43	+ 42 21	1·2	0·80	8·3	11	86·847
125	Glasg. 5087. . .	20 14 35	+ 38 38	194·6	2·80	7	11·3	85·450
126	D. M. 38°.4007	20 14 54	+ 38 36	146·7	2·89	9·7	9·7	86·810
127	W$_2$ 20^h.577 . .	20 16 35	+ 39 06	89·6	1·59	8·5	13	86·261
128	L. 39300	20 18 47	+ 42 36	34·6	0·95	6·3	11	86·847
129	L. 39370	20 21 20	+ 16 33	145·9	4·78	8·5	13	86·711
130	D. M. 36°.4068	20 21 42	+ 36 48	285·4	1·43	8·5	8·7	83·734
131	W$_2$ 20^h.759 . .	20 22 49	+ 18 23	322·8	4·54	7·8	11·2	81·639
132		20 26 07	– 14 07	207·8	6·83	8·5	10	85·229
133	W$_2$ 20^h.612 . .	20 26 09	– 13 57	182·1	0·83	8	8	85·229
134	D. M. 34°.4091	20 30 55	+ 34 45	202·0	3·06	8·5	8·7	82·690
135		20 34 18	– 14 57	223·0	2·44	7·5	12·5	83·742
136	W$_2$ 20^h.1139 .	20 34 19	+ 28 41	6·2	2·51	8	11·5	82·649
137	W$_2$ 20^h.1181 .	20 35 37	+ 29 23	278·9	1·23	6·5	11	85·826

113. ε^2 Sagittarii precedes 2^m 5^s and same declination.

114. A very difficult pair; the wide pair = south 726.

116. The wide pair = H 2908.

120. A rather difficult pair.

121. There is a distant companion 13 mag. p. = 40°, dist. = 42″.

122. 21 Vulpeculæ precedes 39^s and 1′.7 north.

123. 7 mag. star precedes 14^s and 0′.3 north.

124. A close and rather difficult pair. 7 mag. star precedes 1^m 24^s and same decl.

125. In Glasgow Catalogue 6 mag.

126. In the field with the preceding pair.

127. A difficult pair. Σ 2668 precedes 40^s and 3′.5 south.

128. A close and rather difficult pair. 8 mag. star follows 7^s and 0′.3 north.

129. A difficult pair, owing to the faintness of the companion. 6·5 mag. star north 20′ and preceding 25^s.

135. A rather difficult pair. Approximate place.

137. A fine pair, not difficult. Σ 2714 precedes 20^s and 2′ south.

No.	Catalogue.	R. A. 1880.	Decl. 1880.	Pos.	Dist.	Mags.		Epoch.
		h m s	° ′	°	″			
138	L. 40064	20 38 14	+25 10					
	A and B....			349·6	2·62	7	13·5	81·678
	C and D....			329·4	2·74	10·9	11·5	81·677
	A and C D..			306·2	128·10			81·677
139		20 39 07	−24 18	213·2	5·20	9	9	83·742
140	L. 40123	20 39 42	+45 53	313·5	7·20	6·8	12·9	85·291
141	D.M. 18°.4619	20 41 39	+18 51	289·4	1·15	8·4	10·8	81·870
142		20 42 36	− 2 40					
	A and B....			5·8	0·62	8·5	8·7	85·744
	A B and C..			298·6	20·38		13	86·747
143	L. 40221	20 43 36	+46 06	301·±	1·±	6	12	85·914
144	W_2 20^h.1480 .	20 46 56	+19 41	167·9	0·42	7	7	86·786
145	D.M. 34°.4186	20 47 24	+34 46	319·5	7·80	8·7	10·2	86·340
146	W_2 20^h.1543 .	20 48 49	+34 46	56·5	0·37	8	8·1	86·304
147	L. 40731	20 55 30	+36 30	353·3	6·97	7·2	13·3	85·371
148	W_2 20^h.1402 .	20 56 01	+ 3 18	205·0	2·39	7·5	11·5	84·837
149	W_1 20^h.1527 .	21 01 26	−12 10	155·4	0·51	8·5	8·5	85·249
150	W_2 20^h.1884 .	21 02 24	+18 22	135·6	2·97	9	11·5	82·004
151	D.M. 3°.4513.	21 04 54	+ 3 22	190·3	1·05	8·5	8·5	84· 79
152	D.M. 27°.4003	21 07 20	+27 51	320·2	0·49	8·4	8·5	82·665
153	W_2 21^h.269 ..	21 12 40	+33 15	111·0	0·79	8	9	83·550
154	W_2 21^h.283 ..	21 13 04	+30 05	205·1	3·58	7·8	11	82·937
155	W_2 21^h.321 ..	21 14 39	+32 45	31·6	2·18	9	9·5	84·782
156	L. 41557	21 16 16	+40 56	44·8	1·71	7	12	85·844
157	W_2 21^h.402 ..	21 17 55	+31 31	21·3	3·81	7·7	7·7	82·007
158	W_1 21^h.397 ..	21 18 51	−10 25	349·4	1·10	9	9·5	83·781

138. A quadruple of small stars and very difficult.

139. Approximate place. 8 mag. star following 3^s and 4′ north.

140. A rather difficult pair, owing to the faintness of the companion.

141. There is a 13 mag. star, p. = 69°, dist. = 24″.7.

142. Approximate place. 6 mag. star south 15′ and preceding 1^m 47^s.

143. This is an exceedingly difficult pair. I tried it a number of times in 1886, but the seeing was not good enough. I suspected on one night that the small star was on the following side, indicating an error of 180° as given above. The magnitude in D.M. is 6·4.

144. A close and difficult pair.

146. A close and difficult pair.

147. A very difficult pair, owing to the faintness of the companion. There is a distant star, 12·5 mag., p. = 250°, dist. = 27″.

149. A close and rather difficult pair.

150. In D.M. 8·6 mag.

151. 7 mag. star north 4′ and following 7^s.

152. A close and rather difficult pair.

153. In D.M. 7·7 mag.

155. β 446 follows 1^m 4^s and 12′ north.

156. A rather difficult pair.

No.	Catalogue.	R. A. 1880.	Decl. 1880.	Pos.	Dist.	Mags.		Epoch.
		h m s	° ′	°	″			
159	D.M. 43°.3925	21 21 53	+43 18	191·3	6·07	8·5	13	86·854
160	D.M. 42°.4107	21 23 26	+42 33	171·3	1·92	8·3	9	86·867
161	W_2 $21^h.621$ . .	21 26 37	+39 32	358·4	2·80	7	11	81·584
162	D.M. 39°.4586	21 27 52	+39 16	329·1	3·20	9	9·5	83·279
163	W_2 $21^h.723$ . .	21 30 48	+31 05	43·1	6·94	8	13	86·793
164	A.G.L. 77·57 .	21 35 58	+34 32	61·8	3·04	8	8	82·191
165	L. 42332	21 36 57	+18 27	62·7	0·39	8	8·2	86·781
166	W_2 $21^h.926$ . .	21 38 31	+27 18	124·2	0·37	7·5	7.5	86·775
167	D.M. 44°.3916	21 38 49	+44 16	46·4	2·25	9	10	83·821
168	D.M. 43°.4037	21 40 41	+43 23	249·2	1·02	8·2	8·2	85·815
169	W_2 $21^h.1067$.	21 44 31	+35 33	134·8	3·20	8	12	82·681
170	D.M. 38°.4618	21 45 29	+38 52	162·4	0·3 ±	8	8	86·789
171	L. 42657	21 46 45	+27 14	179·0	0·63	8·2	8·2	84·864
172	W_2 $21^h.1124$.	21 47 05	+41 48	87·9	10·50	7	12	86·848
173	D.M. 18°.4888	21 49 36	+18 08	72·6	1·06	8	10	81·696
174	D.M. 36°.4710	21 50 41	+36 43					
	A and B. . . .			154·7	7·32	9	9	81·792
	C and D. . . .			88·6	6·29	10	10	81·795
	A and C. . . .			227·4	161·42			81·785
175	L. 42979	21 56 03	+43 04	302·9	0·98	7	10	85·815
176	W_2 $21^h.1369$.	21 56 15	+22 59	188·1	0·91	8	11·5	81·678
177	L. 43010	21 57 07	+36 24	110·2	8·08	6·5	13	86·274
178	W_2 $22^h.118$ . .	22 06 05	+31 30	224·2	3·60	7	11·7	81·706
179	W_2 $22^h.145$ . .	22 07 11	+29 37	246·3	0·47	8	9	84·852
180	W_2 $22^h.238$ . .	22 10 49	+43 18	42·5	0·50	7·2	7·2	86·845
181	W_2 $22^h.290$ . .	22 13 28	+33 28					
	A and B. . . .			38·1	2·96	8·2	10·7	86·814
	A and C. . . .			298·6	18·44		11	86·826
	A and D. . . .			349·6	27·09		10	86·826
182	D.M. 16°.4723	22 17 37	+16 57	135·0	1·55	8·5	8·5	84·834
183	D.M. 21°.4747	22 19 06	+21 58	216·7	2·07	8·2	11·6	83·253
184	D.M. 42°.4398	22 21 21	+42 55					
	A and B. . . .			293·2	2·30	9	11·5	85·815
	A and C. . . .			314·7	45·04		9	85·775

159. A rather difficult pair, owing to the faintness of the companion. 7·5 mag. star follows 21^s and same decl.

165. A close and difficult pair. Σ 2818 rejected precedes 35^s and 3′ south.

166. A close and difficult pair. 8·3 mag. star 6′ north and 4^s preceding.

170. A very close and difficult pair. 6·5 mag. star 6′ north and 40^s following.

172. 8 mag. star 3′ north and 36^s following.

174. A quadruple of small stars.

176. 8 mag. star 6′ south and 12^s following.

177. A very difficult pair, owing to the faintness of the companion.

179. A close and difficult pair.

180. A close and rather difficult pair. 7 and 8 mag. stars south 6′ and preceding 45^s and 20^s respectively.

182. 7 mag. star north 6′ and following 4^s.

183. 7 mag. star following 42^s and 1′ north.

No.	Catalogue.	R. A. 1880.	Decl. 1880.	Pos.	Dist.	Mags.		Epoch.
		h m s	° ′	°	″			
185	D.M. 37°.4573	22 21 15	+38 01	155·6	2·73	9	11·5	85·844
186	W_2 $22^h.668$	22 30 59	+27 10	23·3	7·38	7	12·2	81·647
187	Rog. 1105	22 34 09	+36 58	286·3	18·34	6	12·9	83·064
188	L. 44361	22 34 46	+36 54	42·6	0·38	8	8	85·808
189	W_2 $22^h.935$	22 41 13	+34 48	339·9	3·60	8·5	13	86·241
190	D.M. 27°.4420	22 43 38	+27 23	152·8	2·04	9·2	9·2	81·793
191	W_2 $22^h.1081$	22 47 53	+30 07					
	A and B			87·9	3·37	7	13	81·750
	A and C			279·4	24·32		10	81·687
192	W_2 $22^h.1211$	22 54 03	+29 26	30·8	1·62	8·5	9·5	84·869
193	W_2 $22^h.1301$	22 57 57	+29 16	169·1	2·83	7·2	11·2	83·833
194	L. 45208	23 00 34	+41 09	59·9	0·3 ±	7	9·3	85·845
195	W_2 $22^h.1372$	23 01 02	+30 02	356·8	3·77	8·4	10·5	84·142
196	D.M. 29°.4868	23 02 33	+29 49	289·6	1·54	8	11	83·542
197	W_2 $23^h.69$	23 05 44	+37 34					
	A and B			110·6	0·44	8	8·3	85·808
	A and C			329·5	42·56		8·5	85·807
	A and D			281·3	47·30		8·5	85·807
198	W_2 $23^h.195$	23 11 32	+16 12	32·4	2·31	8	9	84.834
199	95 Aquarii	23 12 43	−10 16	223·5	1·15	5	11	84.851
200	Rad. 6099	23 24 19	+85 45	137·7	1·73	6·5	12	85.830
201	D.M. 33°.4744	23 31 12	+33 59	341·5	3·59	8	9·3	83·313
202	W_2 $23^h.673$	23 32 29	+39 49	135·3	2·57	8·3	11·8	83·665
203	D.M. 34°.4976	23 33 11	+34 55	128·4	3·53	9	10	81·799
204	W_2 $23^h.947$	23 46 09	+27 55	354·8	5·82	8	10·2	82·889
205	L. 46836	23 47 58	+38 37	179·7	4·56	6·5	12·5	85·773
206	W_2 $23^h.1080$	23 52 58	+33 36	191·1	2·09	8	10	81·741
207	W_2 $23^h.1085$	23 53 01	+40 32	187·2	3·52	7	12·5	83·334
208	W_2 $23^h.1146$	23 55 21	+30 04	235·8	0·67	8	10	84·388
209	D.M. 32°.4755	23 56 12	+32 18					
	A and B			358·7	1·28	8·5	11	84·231
	A B and C			139.0	19·47		13	84·427

185. 7 mag. star following 8^s and 0′.2 north.

188. A close and rather difficult pair. 6 mag. star preceding 34^s and 3′ north. O Σ 475 precedes 1^m 8^s and 10′ south.

189. A rather difficult pair, owing to the faintness of the companion.

191. A difficult pair, owing to the faintness of the companion.

194. A close and exceedingly difficult pair.

196. 7 mag. star 1′ south and 30^s preceding.

197. A close and rather difficult pair.

199. A difficult pair, owing to the closeness and inequality of the components.

200. A fine pair, not difficult.

206. Σ 3050 32′ south and 20^s following.

207. The north star of a small triangle.

APPENDIX C.

NEBULÆ FOUND AT THE DEARBORN OBSERVATORY, 1866-8.

The following is an extract from my journals of observation of 1866-8, or rather from a copy of a portion of these journals. It was drawn up at the request of Mr. Colbert, in order to complete the record of observed nebulæ.

As I have had no access to the original journals, and here at Williamstown have no copies of the principal catalogues of nebulæ, I must simply rely upon my remembrance that the positions were carefully determined (by circle-readings after placing the objects in the centre field), and that in most cases the zero-points of the circles, including chronometer-correction, was immediately secured by a neighboring bright star.

I can not, of course, guarantee the accuracy of the positions; but at the time took pains immediately to reduce the observations, and, if I remember rightly, to assure myself that the nebulæ in question were not in Herschel's general catalogue. The numbers are current,* from the beginning of the work upon the nebulæ till 1868, when I began the use of the meridian circle.

During those early years I was much troubled with sight-seers, and more with the faulty construction of the old dome and its shutters. These blundering contrivances greatly restricted the work which it was possible to do, and especially conditioned the declinations in which, from time to time, I found it practicable to work.

Before undertaking these labors, I had given my time chiefly to observations of precision, and took up this subject of the nebulæ mainly to gain a practical acquaintance with these very interesting bodies. In 1868, I began the Zone 35° to 40° with the meridian circle, in order not to be without solid scientific work, and continued it until interrupted by the great fire of 1871. It was only some years afterward that the great dome was taken down and replaced by one of a more practicable construction. Family cares made it necessary for me to attend to a more practical department of astronomy from 1871 to 1876, in which year I accepted the Field memorial professorship in Williams College.

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* Nos. 1, 4, 17 were afterwards found identical with known nebulæ.

* Nos. 86, 88, 95, 100, and 101 were found by Mr. A. N. Skinner, then assistant at Dearborn Observatory.

TRUMAN HENRY SAFFORD.

NEBULÆ FOUND AT THE DEARBORN OBSERVATORY, 1866-8.

No.	AR. 1870·0.	Decl. 1870·0.	Description.	Date.
	h m s	° ′ ″		
2	12 54 23·4	+29 44·7	pF	1866, May 3
3	55 23	29 44	FbN	3
5	14 19 18	28 55·4	pF	4
6	28 10	32 16·0	pF	4
7	15 30 16	23 54·8	pF	4
8	14 21 36	31 33·9	no description	9
9	15 34 09	21 05·1	no description	9
10	15 51 15	22 47·2	neb.*	9
11	12 35 09	26 44·5	F	11
12	12 35 15	26 46·2	F	11
13	14 25 40	31 48	pB	11
14	13 46 06	23 11	pF	14
15	14 16 59	24 23	F	14
16	14 25 08	29 48	bN	14
18	12 13 00·5	29 01·3	vF	14
19	12 13 16·8	30 36·6	F	16
20	12 16 10·7	30 37·7	vB probably well known	16
21	12 31 57·2	29 39·1	F	16
22	12 47 48·0	27 09·0	neb.* 12^m	16
23	12 52 02·5	27 06·2	pB	16
24	15 23 41	13 26·5	pB diam 30″	June 1
25	15 41 03	18 19·3	pB see good nucl.	1
26	12 20 29	23 21·2	bN (12^m)	6
27	13 36 28	25 08·0	nucleus 13^m	6
28	13 34 41	25 09·8	no description	6
29	17 14 06	16 48·0	F	6
30	18 06 28	21 25	pB	6
31	18 07 00	21 24	pF	6
32	18 33 24	25 15	pB pL	6
33	18 06 03·5	31 05·8	bN (12^m) diam. 20″	7
34	18 32 54·5	25 13	pF	9
35	18 36 02·4	36 08	vmbM 40″ diam. nucl. 12^m	9
36	19 26 02·4	35 29	vF undefined	9
37	19 26 37·8	35 35	vF 30″ diam. w. small cluster	9
—	14 56 13	26 30·3	doubtful	15
38	16 52 04	28 03	vF vS iF	July 11
39	16 52 18	28 03	FSbM	11
40	16 52 48	28 02·5	pB S vmb M	11
41	17 46 27	24 30·0		11
42	19 06 05	30 19·7	SpB FmbM	12
43	19 49 47·8	28 56·2	pS F bMR	12
44	16 52 52	20 16·0	vF nearly R not vmb M pS	Aug. 1
45	17 22 06	+26 36·2	SbM pF	1

34. Same as 32?

—. Not numbered; place probably in error.

45. Precedes another H III·137 by 11^s.

No.	AR. 1870·0.	Decl. 1870·0.	Description.	Date.
	h m s	° ′ ″		
46	17 56 11·5	+19 45·9	pB vmb M pS	Aug. 1
47	18 23 33	22 49·2	pS pB vmb M	9
48	17 38 20	25 52·8	pB pL vmb M (bi N ?)	28
49	17 19 25	29 31·2	neb.* 11^{m}	Sept. 5
50	21 30 08	34 49·1	neb.* pB vmb M	12
51	20 50 50	30 33·9	possibly connected with h 2093	13
52	21 57 03	14 29·3	vF vS neb M	14
53	22 32 47	33 18·6	no description	14
54	18 33 14	39 56·7	pB pS gbM	28
55	21 20 52	18 05·5	pS pF iF	29
56	22 22 10	16 07·4	pS neb M N pF	Oct. 1
57	22 39 23	20 23·0	vS RbM N 13^{m}	1
58	23 04 55	28 55·3	F pS F gbM	1
59	23 08 57	29 50·2	a small cluster ?	1
60	0 24 28	30 06·0	probably a small cluster	8
61	1 26 09	35 01·2	S pF R bM	10
62	1 05 49	38 03·9	pS pB gar bM	29
63	1 26 11	30 00·8	pF vS probably a well-known outlier of M 33	Nov. 1
64	1 52 49	30 40·7		5
65	0 31 33	28 47·7	neb.* 13^{m}	5
66	0 54 21	30 22·4	F iF lb M	8
67	1 51 15	35 58·6	pF neb M $N = 13^{m}$	8
68	1 52 03	30 17·3	S pF iF gbM	9
69	1 13 07	28 59·2	pS pB vmb M $N = 12^{m}.13$	Dec. 1
70	3 36 24	31 45·2	vL vgbM pB	1
71	1 59 53	30 33·0	pB pL RbM	4
72	1 42 10	20 04·4	pB pS bM $N = 13^{m}$	27
73	3 56 06	21 47·6	F S R $N = 13^{m}.5$	1867, Jan. 1
74	7 25 54	33 05·8	pS pB vmb M $N = 12^{m}.13$	Feb. 5
75	15 44 34	19 19·4	no description	Apr. 24
76	16 09 55	19 46·3	double nebula pF dist 40″	24
77	15 59 28	15 22·9	S pF bM $N = 12^{m}.5$	26
78	14 22 05	+14 21·7	pL F vgbM R	27
79	20 13 56	−12 45·5	pB S R $N = 12^{m}$	Aug. 24
80	20 13 38	−12 44·5	no description	24
81	18 09 10	−19 46·4	* 10^{m} pF nebulosity	28
82	18 47 34	− 8 57·3	pL pB gb M	28
83	20 29 28	− 5 01·2	no description*	29

48. Position not certain.

49. Decl. 29°.41′.2 ?

64. Don't understand *copy* of notes.

70. A loose cluster with nebula.

83. Position doubtful [5966]. I suppose these numbers [5966] refer to a continuation of G.C. not within my reach. They were inserted by some one since I left Chicago. The numbers of G.C. end with 5079, and contains all nebulæ then (1866) known to me.

83.* From this point on the descriptions have not been copied from the observing book into the book sent me. T. H. S.

No.	AR. 1870·0.	Decl. 1870·0.	Description.	Date.
	h m s	° ′ ″		
84	22 21 35	− 3 33·4		Sept. 19
85	21 17 50	− 6 18·0		21
86	22 49 00	− 6 12		21
87	23 52 51	− 4 52·7		23
88	23 58 25	− 7 50·5		23
89	0 12 21	− 4 00·6		23
90	0 20 26	− 2 29·8		23
91	0 20 44	− 2 29·3		23
92	0 21 19	− 2 31·8		23
93	22 49 35	+ 3 14·6		27
94	0 36 43	− 0 51·2		27
95	1 26 17	− 1 20·8		27
96	0 11 00	+ 10 42·6		30
97	0 28 58	+ 8 24·7		Oct. 22
98	2 00 47	− 2 00·7		22
99	23 47 31	− 0 20·6		23
100	1 24 12	− 2 41·3		23
101	2 03 02	− 10 17·4		23
102	3 00 15	− 1 17·5		31
103	2 31 41	+ 1 33·0		Nov. 1
104	13 13 28	− 11 52·3		1868, May 20
105	13 56 55	− 9 30·6		20
106	14 44 58	− 6 42·1		23
107	12 15 32	+ 30 47·8		June 11
108	11 51 42	+ 10 43·1		12

84. Position doubtful [6053].
85. Probably = G.C. 4654.
99. [6230.]
103. [5266.] My own note is that this nebula possibly = G.C. 581.
104. G.C. 3489?
105. [5785?]
107. See No. 20.
108. [5598.]

APPENDIX D.

Description of a Printing Chronograph.

PROF. G. W. HOUGH.

(Reprinted from the "Sidereal Messenger").

About the year 1848, the idea of recording astronomical observations by the use of galvanic electricity was put in successful operation by different individuals. Since that time, chronographs of various forms have been constructed for recording in a legible manner, on a moving sheet of paper, the time of any phenomenon observed. The great superiority, in point of accuracy and saving of labor over the old eye and ear method formerly used, soon led to the general adoption of the new plan.

The idea that type-wheels might be substituted for the moving paper, and a printed record made, was long ago entertained by astronomers, and various plans were devised for accomplishing this purpose.

In the year 1865, in a paper read before the Albany Institute, I gave an outline of a plan for a printing chronograph, radically different from any that had been proposed. It was based on the principle of using separate systems of mechanism for the fast-running type-wheel, and those recording the integer minutes and seconds. These two trains to be simultaneously controlled by the sidereal clock, and to be entirely independent of each other.

In the year 1871, I completed a printing chronograph based on this method.

This machine was in constant use at the Dudley Observatory for three years, demonstrating the practicability of such an apparatus.

In this first machine the blow for printing was done by a hammer, elevated by a heavy train of clock-work, which made the instrument somewhat unwieldy. The type-wheels were constructed by soldering electrotype strips on the rim of a brass disc, and required to be renewed once a year or oftener. In other respects the machine was entirely satisfactory.

About a year ago, I put in operation at the Dearborn Observatory the printing chronograph about to be described. Since the machine was first set up, the mechanism has been modified in various ways in order to bring the instrument in as compact and convenient a form as possible.

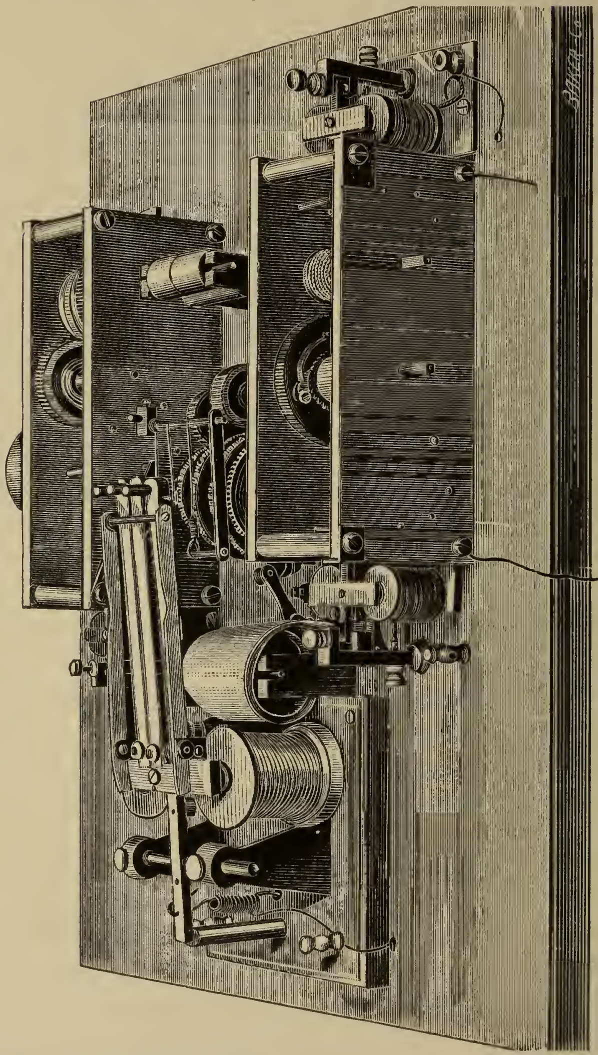
The accompanying wood-cut will aid in making a description of the machine intelligible. The relative size of the different parts may be inferred from the statement that all the mechanism rests on a table eighteen inches by twenty-four inches.

First, the movement in the rear consists of a system of clock-work, carrying a type-wheel with fifty numbers on its rim, revolving once every second; one, two, or parts of two numbers being always printed, so that hundredths of seconds may be indicated.

This train is primarily regulated to move uniformly by the Frauenhöfer friction balls, and secondarily by an electro-magnet acting on the fast-moving type-wheel and controlled by the sidereal clock. This train is entirely independent and can be stopped at pleasure, without interfering with the other type-wheels.

Second, the movement in front consists of four shafts for carrying the type-wheels indicating the minutes and seconds. The motion of this train is also governed by an electro-magnet, controlled by the sidereal clock, operating an escapement in a manner analogous to the action of an ordinary clock; every motion of the escapement indicating integer seconds, advancing the type one number. There are three type-wheels indicating minutes, seconds, and hundredths of seconds. The integer seconds are advanced at every oscillation of the standard pendulum, and the minute at the end of each complete revolution of the seconds' wheel.

The type were cut on solid cast-brass discs, and will probably wear as long as other parts of the mechanism.



HOUGH'S PRINTING CHRONOGRAPH.

Third, in the right-hand end of the front movement there are three shafts, for moving the paper fillet on which the record is made.

The large electro-magnet operating the printing hammer is seen on the left, and directly under the hammer-arms is the spool of paper. When the machine is ready for use, the end of the paper is drawn over the tops of the type-wheels and passed between the brass rollers between the two movements.

The train for moving the paper is unlocked by an electro-magnet whenever an impression is made, or it may also be unlocked independently by a duplicate observing key, so as to leave a blank space of any desired amount between the records for different stars or groups of wires.

The paper fillet is two inches in width, and the spool will hold about forty feet—sufficient for 1200 observations, including the spacing for different objects.

The type are inked by means of small rollers covered with cloth, resting against their rim, and revolving with the wheel by friction. These rollers require inking every two or three days. The inking rollers, however, may be dispensed with, and impression ribbon used instead; but it is not nearly so handy, and, besides, requires a heavier blow to get a good impression.

The blow for making the impression is struck by means of the electro-magnet of one ohm resistance. The hammer-arms are flexible. When the armature is pressed down without striking a blow, the hammers stand about one-half inch above the type. The impression is therefore made from the spring of the arms, and not by a direct blow.

By this device, which is regarded of the greatest importance, the motion of the type-wheel is not disturbed an appreciable amount. None of the type-wheels are stopped in the act of printing.

If the record is made while the type-wheel indicating integer seconds is in the act of escaping, two numbers, or one number and part of another, is printed, so there is no ambiguity; this condition, of course, only occurs when the hundredths of seconds' wheel indicates 0.98 to 0.02 seconds. If two integer seconds are printed when, for example, the hundredths read 0.98, the smaller number is the correct one.

The battery for operating the printing magnet consists of three storage cells, charged in series by means of eight gravity elements. The charging battery is kept permanently connected with the storage cells. By means of this compound battery, there is always sufficient current to operate the recording and printing chronographs at the same time—as well as an electric bell—in all eight pairs of electro-magnets.

The storage cells each consists of two lead plates, four by six inches, coated with red lead, and hung vertically in a glass jar containing dilute sulphuric acid. The lead plates may be kept in constant use for one year without renewal.

Aside from the printing magnet, the electrical power required is essentially the same as for a recording chronograph.

The printing magnet might be operated with three Grove cells or their equivalent.

The machine is readily set to indicate the time given by the clock's face.

The hundredths-of-seconds' wheel needs no adjustment, as it is permanently set to print zero, when the connection is made by the clock pendulum.

The integer seconds are set with the clock by rapidly operating the escapement by hand; and the minute wheel may be moved in either direction.

It requires about two minutes to get ready for observing, including the preparation of the inking rollers.

In observing zone stars with our first machine, it was found advantageous to set the type to print directly the nearest integer seconds of mean right ascension so that the final reduction was always a small quantity.

During the construction of the present machine, a great many experiments were made to ascertain the probable error due to our method of control. For this purpose, the standard mean time signal clock was arranged to operate the printing magnet once each minute. By this means, the comparison between the sidereal and M. T. clocks was made for every part of the second. The difference between two successive records and 0.164 second gave the error of any impression.

By employing an ordinary train (similar to that used in a cheap clock) for driving the hundredths-of-seconds' wheel, the "mean" error was about ± 0.03 second, and the maximum possible error ± 0.08. This train was so imperfect that it was necessary to make it gain 0.20 second in every second in order to carry it over the hard places. The train now used is ordinary gear, accurately cut but not polished. The "mean" error is found to be ± 0.015 second, with a possible maximum error ± 0.05 second.

In order to secure the best possible results, the train for driving the hundredths-of-seconds' type-wheel should be as accurately constructed as that used for an astronomical clock, then the "mean" error would be less than ± 0.01 second and the maximum possible error would not exceed ± 0.03 second.

The theory of control, for securing hundredths of seconds, is as follows: A train of clock-work is regulated, by any suitable device, to run with approximately uniform velocity, but always a little fast; the final control is then secured by an electro-magnet, checking its velocity once every second. The whole train may be checked or only the type-wheel shaft, the latter being driven by friction.

By employing the first method the probable error of any impression is a little less than for the latter.

When the whole train is regulated, however, and it is stopped by design, it may require several seconds for the type-wheel to come in coincidence with the sidereal clock, whereas when the type-wheel shaft is driven by friction only, the coincidence will be secured in one or two seconds.

The train for carrying the integer minutes and seconds' type will run about ten hours without winding, requiring a weight of seven pounds, single cord. The train for running the paper fillet requires about two pounds weight, single cord. The train for hundredths of seconds will run one hour and forty minutes and requires a weight of fourteen pounds, single cord.

The saving of time and labor by the use of a printing chronograph is very considerable.

In an observatory, when systematic meridian work is done, the saving in labor for a single year would probably amount to more than the cost of the machine.

APPENDIX E.

COMPANIONS OF SIRIUS.

[I avail myself of the opportunity to republish the result of my work on the orbit of the Clark companion of Sirius. It was sent to a few friends, only, in August 1880, and was subsequently reproduced, in part, in the report of the Chicago Astronomical Society, and in the *Sidereal Messenger.* The agreement between the predicted and the observed position angles since 1880 is so close as to warrant its preservation. I could not at present suggest any change in the elements beyond the remark that the unit of distance chosen appears to be too small. The mathematician will have no difficulty in seeing the possibility of this, especially when he knows the crudity of the earlier measures of distance. The paper is reproduced with no change other than the correction of an error in the printing. The figure 4 was dropped out of the form after final revision, making it appear that the angle between the axis and node line is only 9 degrees, whereas the computation gave the angle as "49 degrees nearly."]

[Copy.]

TRIBUNE OFFICE,
CHICAGO, August----, 1880.

Prof.......................................

The accompanying elements of Orbit, calculated by me, for the Clark Companion of Sirius, may interest you.

The subjoined speculations in regard to the existence of another star may be open to the charge that, owing to the great brilliancy of the principal star, the observations are too widely discordant to warrant the inference. I therefore do not send them to any journal, scientific or otherwise; but to the few individuals whose expressions of opinion in regard to the matter would be highly valued by

Yours very respectfully,
E. COLBERT.

The numerous measures of relative position of Clark's Companion to Sirius, seem to me to be best satisfied by the values given in the second and third columns of the following table:

Date, A.D.	*Observed Position Ang. Degrees*	*Apparent Distance Seconds*	*Mean Position Ang. Degrees*	*Perturbation Degrees*
1862·2	84·6	9·0	84·1	+ 0·5
1863·2	81·8	9·35	81·4	+ 0·4
1864·2	79·1	9·7	78·85	+ 0·25
1865·2	76·6	10·0	76·45	+ 0·15
1866·2	74·25	10·3	74·25	0·
1867·2	72·0	10·55	72·15	− 0·15
1868·2	69·9	10·75	70·1	− 0·2
1869·2	67·9	10·95	68·15	− 0·25
1870·2	66·0	11·1	66·3	− 0·3
1871·2	64·1	11·25	64·45	− 0·35
1872·2	62·35	11·35	62·65	− 0·3
1873·2	60·65	11·4	60·9	− 0·25
1874·2	58·9	11·4	59·1	− 0·2
1875·2	57·2	11·35	57·35	− 0·15
1876·2	55·45	11·25	55·55	− 0·1
1877·2	53·65	11·1	53·7	− 0·05
1878·2	51·8	10·9	51·8	0·
1879·2	49·9	10·65	49·85	+ 0·05
1880·2	47·9	10·3	47·8	+ 0·1
1881·2	- - -	- - -	45·55	+ 0·15

Correcting these position angles (in second column) for precession to 1880, I deduce the following as the elements of the orbit:

Semi-axis major,	8·41 sec.	Eccentricity,	0·58
Mean motion,	7·26 deg.	Period,	49·6 years.
Inclination,	57·1 deg.	Position of Node,	42·4 deg.

Date of Apastron passage, A. D., 1867·0; giving, Node to Periastron, 133·0, measured in the direction of the star's (retrograde) motion.

[For the apparent orbit, a = 7·682 secs.; e = 0·848; angle between axis and node line, 49 degrees, nearly.]

These elements give the numbers in the fourth column of the table, as successive values of the position angle. As an eminent astronomer has remarked, "they agree with the observations very well." But the differences, given in the fifth column, are so methodical as to suggest the existence of a disturber; with a period of 20·4 years, and present position angle of about 205 degrees, with apparent distance about 4 seconds, if moving in a circular orbit. The direction retrograde. Of course an orbit with very small eccentricity is mathematically inconsistent with perturbation by such a mass as the known comes; but it is scarcely worth while to attack that part of the problem at present.

It may be noted that the ratio of mass of the disturber to that of Sirius, as indicated by the above stated results of perturbation, compares with that of Jupiter to the sun; though small by the side of the mass deduced from meridian observations for the known companion.

The preceding elements give the following as the *undisturbed* places of the Clark Companion for several subsequent years.

Date.	*Pos. Angle. Degrees.*	*App. Dist. Seconds.*	*Date.*	*Pos. Angle. Degrees.*	*App. Dist. Seconds.*
1881·2	45·55	9·9	1888·2	12·9	4·3
1882·2	43·1	9·45	1889·2	356·1	3·1
1883·2	40·4	8·85	1890·2	322·2	2·2
1884·2	37·25	8·2	1891·2	273·9	2·3
1885·2	33·5	7·4	1892·2	242·5	3·15
1886·2	28·8	6·5	1893·2	224·6	3·9
1887·2	22·4	5·6	1894·2	211·6	4·4

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